(19) DANMARK

(10) **DK 177845 B2**

(12) PATENTSKRIFT

Ændret efter indsigelse

Patent- og Varemærkestyrelsen

(51) Int.Cl.: ***F 01 M 1/02 (2006.01)*** ***F 01 M 1/16 (2006.01)***

(21) Ansøgningsnummer: **PA 2013 00272**

(22) Indleveringsdato: **2013-05-10**

(24) Løbedag: **2013-05-10**

(41) Alm. tilgængelig: **2013-11-16**

(45) Patentets meddelelse bkg. den: **2014-09-15**

(45) Patentets ændring bkg. den: **2015-06-22**

(30) Prioritet: **2012-05-15 DK PA 2012 00344** **2012-10-16 DK PA 2012 00636**

(73) Patenthaver: **MAN DIESEL & TURBO, FILIAL AF MAN DIESEL & TURBO SE, TYSKLAND, Teglholmsgade 41, 2450 København SV, Danmark**

(72) Opfinder: **Jørgen Meyer, Langholm 5, 4000 Roskilde, Danmark**
Carsten Bredahl, Rønnevangshusene 166, 2630 Taastrup, Danmark
Niels Skou Larsen, Lotusvej 45, 2300 København S, Danmark
Ole Sørensen, Engvej 9D, 2625 Vallensbæk, Danmark

(74) Fuldmægtig: **NORDIC PATENT SERVICE A/S, Bredgade 30, 1260 København K, Danmark**

(54) Benævnelse: **ANORDNING TIL CYLINDERSMØRING TIL EN STOR, LANGSOMT KØRENDE, TOTAKTSDIESELMOTOR OG FREMGANGSMÅDE TIL ANVENDELSE AF CYLINDERSMØRINGSSYSTEMET**

(56) Fremdragne publikationer:
DE 19743955 A1
WO 2009015666 A1
WO 2008009291 A1
WO 2006089558 A1
WO 2008141650 A1
CH 673506 A5
EP 0622528 A1

(57) Sammendrag:
A cylinder lubrication device (1) for a large slow running two-stroke diesel multi-cylinder engine having in each cylinder (110) a reciprocating piston (120) with piston rings (121) that slide on the inner surface of the cylinder liners (111) whereby the cylinder lubrication device (1) provides the inner surface of the cylinder liners with a precisely dosed quantity of cylinder lubrication oil for each reciprocation of the piston (120) via a plurality of injection points that are distributed at equal level around the circumference of a cylinder, the cylinder lubrication device (1) comprises a plurality of piston pumps having a dosing plunger (30) slidably movable in the dosing cylinder (20) between a start position (S) and an end position (E), a common drive (31) including a linear actuator (41,46) for driving all of the dosing plungers (30) simultaneously, the dosing plungers (30) having a predetermined full stroke between the start position (S) and the end position (E), wherein the diameter of the dosing cylinders is such that the precisely dosed quantity is delivered by moving the dosing plungers (30) over a fraction of the maximum stroke so that the dosing plungers (30) can be moved in part strokes a

Fortsættes ...

plurality of times in the direction from the start position towards the end position before the dosing plungers need to be returned to the start position.

Fortsættes ...

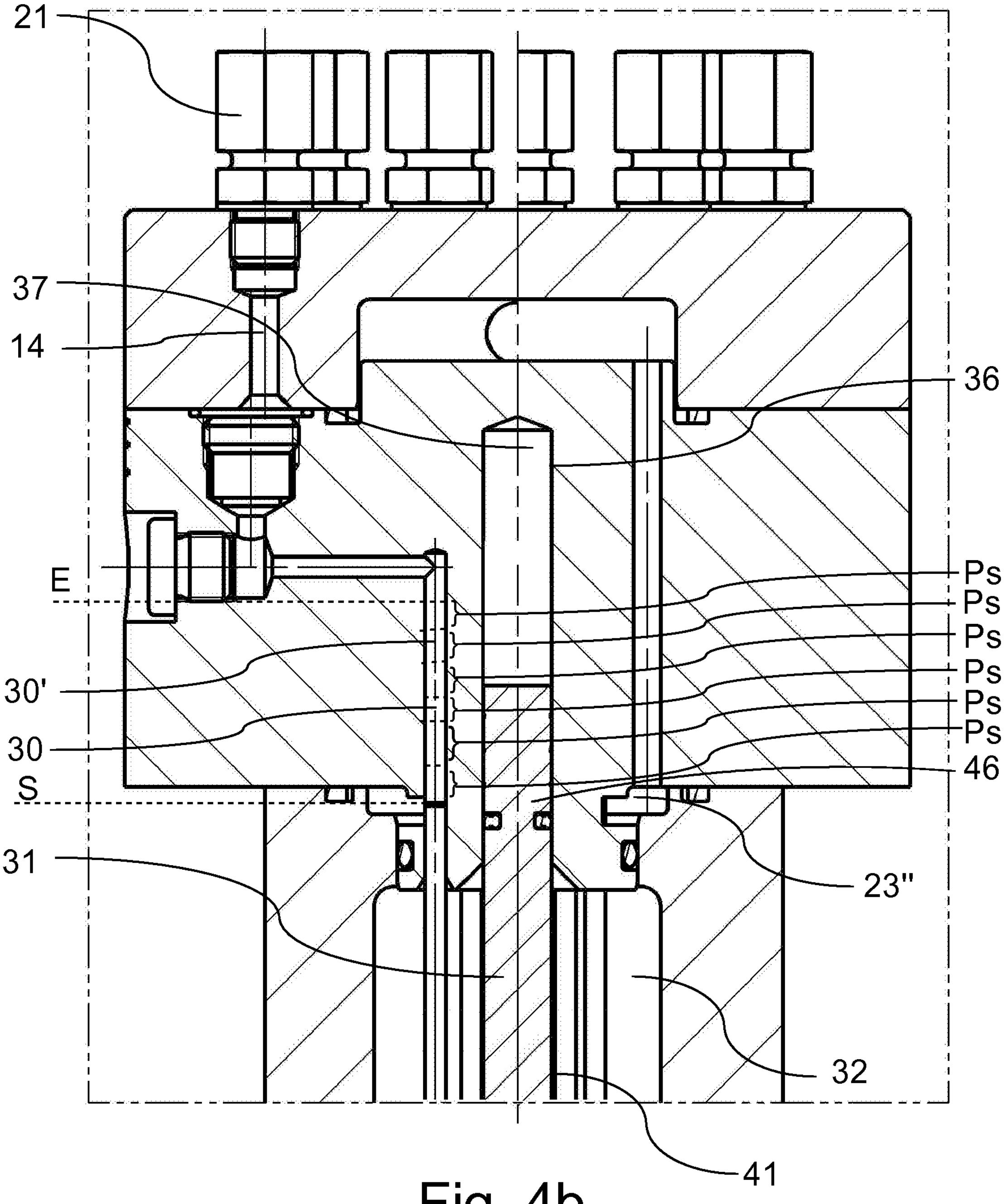

Fig. 4b

DK 177845 B2

A CYLINDER LUBRICATION DEVICE FOR A LARGE SLOW RUNNING TWO-STROKE DIESEL ENGINE AND METHOD OF OPERATING THE CYLINDER LUBRICATION SYSTEM

The present invention relates to a cylinder lubrication device for a large slow running two-stroke diesel engine and to a method of operating the cylinder lubrication system.

More particularly the invention relates to a cylinder lubrication device for a large slow running two-stroke diesel engine with a plurality of piston pumps that are moves simultaneously by a common drive.

The present invention further concerns a hydraulically activated cylinder lubricator and an operation control method for dosing of cylinder oil according to the engine designers specification and according to engine operating conditions, load, and user demand.

BACKGROUND ART

In the field of large two-stroke diesel engines with crossheads, such as for use in power plants or as prime movers in marine vessels, cylinders and pistons of the engine have a need for a particularly precise and extensive lubrication. Typically, such engines run on the cheapest available type of fuel, which is often heavy fuel oil. Heavy fuel oil introduces large quantities of particles that are harmful to the engine into the cylinders, such as sulfur that forms sulfuric acid in the combustion process. This causes the need to protect the cylinder walls from the attack by the sulfuric acid by applying cylinder lubrication oil with a low pH value to inner surface of the cylinder liner in order to compensate for the acid (high pH) combustion gas components. The cylinder lubrication oil is relatively costly and the cylinder lubrication oil that is applied to the inner surface of the cylinder liner is consumed during engine operation, i.e. a continuous fresh supply is needed during engine operation. The consumption of cylinder lubrication oil is significant factor in the operation of a large slow running two-stroke diesel engine with crossheads. Consequently, there is a need for efficient and accurate lubrication of the engine cylinders and pistons, ensuring proper protection of the latter and minimal consumption of the costly cylinder lubrication oil.

The cylinder lubrication oil consumption represents a large expenditure for an engine operating with the nominal guiding feed rate, and especially for large bore engines (600-1200 cm bore), even a minute reduction in the dosage per injection of lubrication oil represents a significant saving of lubrication oil consumption in normal use of large engines. The injection of lubrication fluid is dosed after engine load and engine status, as well as after the fuel properties. The fuel injections are usually timed, such that injections are made regularly relative to the revolutions of the engine, and when the engine piston passes the lubrication quills. The injection quills are distributed evenly on the engine cylinder circumference and in position corresponding to the engine piston position in a predefined phase of the engine cycle, e.g. at the end of the expansion of the combustion gas. The lubrication fluid is injected when the engine piston is at the level of the quills, because this reduces the risk of burning the costly lubrication fluid (if injected above the piston), and the risk of draining the lubrication fluid off (if the lubrication fluid ends up below the piston).

Consequently, it is an object of the present invention to reduce the cylinder lubrication oil dosage while maintaining a satisfactory piston/liner wear rate and maintaining or improving the time between engine overhauls. Reduced lubrication oil consumption also has a positive effect on the environment as emissions will be lower.

DE19743955 discloses a cylinder lubrication device according to the preamble of claim 1. This cylinder lubrication device make a single variable length injection stroke and thereafter the dosing plungers return to their state position again. The variable length stroke is seldom reaches the full stroke that the dosing plungers are capable of, and thus wear on the components such as the dosing plungers, the dosing cylinders and the actuator are concentrated on the first part of the injection stroke.

Typical lubricators are based on the principle of injecting a specific volume of lubrication oil into the cylinders via a number of injection points or quills for every four (or every five or six, etc.) revolutions of the engine. This is often dictated by the minimum time it takes for the typical lubricators to get ready to perform another injection of lubricant after an injection. In pneumatic systems and traditional hydraulic systems this time is determined by the limitation in the speed with which injection chambers can be refilled before an injection, and the limitations in the control of the dosages and speed of injections. Therefore the dosing is made with a certain surplus of lubrication oil, causing an increased consumption of lubrication oil.

If on the other hand a lower consumption is desired, the cylinder lubrication oil must be injected into the cylinder at the exactly correct position and time, where the effect is optimal. This is not always possible with the conventional lubricators of today.

DISCLOSURE OF THE INVENTION

On this background, it is an object of the invention to provide a lubricator and engine with a lubricator that overcomes or at least relieves the problems of the prior art. It is as further object of the invention to provide an alternative cylinder lubricator and method of operating a cylinder lubricator.

This object is achieved by providing a cylinder lubrication device for a large slow running two-stroke diesel multi-cylinder engine having in each cylinder a reciprocating piston with piston rings that slide on the inner surface of the cylinder liners whereby the cylinder lubrication device provides the inner surface of the cylinder liners with a precisely dosed quantity of cylinder lubrication oil for per reciprocation or per number of reciprocations of the piston via a plurality of injection points that are distributed at equal level around the circumference of a cylinder, the cylinder lubrication device comprises a plurality of piston pumps having a dosing plunger slidably movable in the dosing cylinder between a start position (S) and an end position

(E), a common drive including a linear actuator for driving all of the dosing plungers simultaneously, wherein the common drive comprises a double acting hydraulic- or electric actuator comprising a first hydraulic- or electric actuator for effecting movement of the dosing plungers in the direction from the start position towards the end position and includes a second hydraulic- or electric actuator for effecting movement of the dosing plungers in the direction from the end position towards the start position, the dosing plungers having a predetermined full stroke between the start position (S) and the end position (E), wherein the diameter of the dosing cylinders and the full stroke of the dosing plunger are such that the precisely dosed quantity is delivered by moving the dosing plungers over a fraction of the maximum stroke so that the dosing plungers can be moved in part strokes a plurality of times in the direction from the start position towards the end position before the dosing plungers need to be returned to the start position, the device further comprising an electronic control unit configured for activating the first actuator to move the dosing plungers over a variable length part stroke each time that a precise dose of cylinder lubrication oil is to be delivered to the cylinder and the electronic control unit is configured to activate the second actuator for returning the dosing plungers (30 to their start positions (S) when the dosing plungers have reached their end positions (E).

By choosing the diameter of the dosing cylinders and the length of the full stroke, i.e. the displacement volume such that a fraction of the full stroke corresponds to a single dose, it becomes possible to operate the cylinder device with a plurality of part strokes before a return/refill stroke needs to be made. Thus, the dosing plungers will always make a full stroke in both directions, be it that in the injection direction the full stroke is achieved by a plurality of part stroke. Thus, wear on the dosing plungers, wear on the dosing cylinders and wear on the actuator and drive mechanism is evenly distributed over the full length of the stroke, thus increasing the lifetime of the cylinder lubricating device.

By providing an actuator for the return/refill stroke the return stroke can be achieved faster and more reliably than with the helical springs used in prior art cylinder lubrication devices.

In an embodiment the common drive comprises a plunger connector connected to the plungers and arranged to move the dosing plungers in the dosing cylinders simultaneously, a double acting linear actuator comprising a first hydraulic linear actuator for effecting movement of the dosing plungers in the direction from the start position towards the end position, and a second hydraulic linear actuator for effecting movement of the dosing plungers in the direction from the end position towards the start position.

In an embodiment the cylinder lubrication device further comprises a position sensor arranged to detect the position of the dosing plungers in the dosing cylinders , and communicating with the electronic control unit.

In an embodiment the electronic control unit determines the presently required dose of lubrication oil or receives information about the presently required dose of lubrication oil and the electric control unit is configured to move the plungers in a part stroke over a distance that corresponds to the determined or received required dose of lubrication oil by activating the first actuator accordingly.

In an embodiment the electronic control unit is configured to control the length of the part stroke of the dosing plungers based on engine operating conditions, preferably adjusting the stroke length to engine operating conditions for each injection event.

In an embodiment the electronic control unit, based on the measured movement of the dosing plungers determines how much the dosing plungers moved in the last part stroke and wherein the electronic control unit compensates for any deviation from the desired value for the last part stroke when determining the desired length of the following stroke of the dosing plungers .

In an embodiment the cylinder lubrication device further comprises a hydraulic valve connected to the first hydraulic linear actuator and connected to the second hydraulic linear actuator and the hydraulic valve being configured to selectively connect the first hydraulic linear actuator to a source of hydraulic pressure and configured to selectively connect the second hydraulic linear actuator to the source of hydraulic pressure.

In an embodiment the hydraulic valve is an on/off type valve and wherein the electronic control unit is configured to control the part stroke of the dosing plungers by controlling the length of the period during which the on/off valve connects the first hydraulic linear actuator to the source of hydraulic pressure.

In an embodiment the electronic control unit is configured to instruct the on/off valve to connect the second hydraulic linear actuator to the source of hydraulic pressure (P) when the dosing plungers have reached their end position (E) so that the dosing plungers by action of the second hydraulic linear actuator are returned to their start positions (S).

In an embodiment the on/off valve is configured to connect the second actuator to tank (T) whilst the first hydraulic linear actuator is connected to the source of pressure (P) and vice versa.

In an embodiment the hydraulic valve is a proportional valve (140) and wherein the electronic control unit is configured to adjust the shape of profile of the speed of the movement of the dosing plungers in a part stroke.

In an embodiment the cylinder lubrication device further comprises the electronic control unit and the cylinder lubrication device are configured to control the length of the part stroke and/or speed of the dosing plungers based on specific cylinder operating conditions.

The object above is also achieved by providing a large slow running two-stroke diesel engine with crossheads (100), comprising a plurality of cylinders, a piston reciprocally movable in each cylinder each of the pistons comprising at least two piston rings, and a cylinder lubrication device as described here above.

In an embodiment the electronic control unit is both an engine control system (ECS) and a control system for the cylinder lubrication device.

The object above is also achieved by providing a method for operating a cylinder lubrication device for a large slow running two-stroke diesel multi-cylinder engine having in each cylinder a reciprocating piston with piston rings that slide on the inner surface of the cylinder liners whereby the cylinder lubrication device provides the inner surface of the cylinder liners with a precisely dosed quantity of cylinder lubrication oil per reciprocation or per number of reciprocations of the cylinder via a plurality of injection points that are distributed at equal level around the circumference of a cylinder, the cylinder lubrication device having a plurality of piston pumps, each piston pump having a dosing plunger slidably movable in the dosing cylinder between a start position (S) and an end position (E), the movement of the dosing plungers between the start position (S) and the end position (E) forming a full stroke, and a common drive including a linear actuator for driving all of the dosing plungers simultaneously in both directions between the start position (S) and the end position (E), the method comprising moving the dosing plungers simultaneously by means of the linear actuator in a plurality part strokes from the start position (S) to the end position (P) for creating a plurality of cylinder oil injection events and when the dosing plungers have reached their end position (E) moving the dosing plungers simultaneously by means of the linear actuator in one full stroke from the end position (E) back to the start position (S).

In an embodiment the method further comprises determining or obtaining the presently required dose of lubrication oil and instructing the linear actuator to move the dosing plungers in a part stroke over a distance that corresponds to the determined or received required dose of lubrication oil.

In an embodiment the method further comprises measuring the movement of the dosing plungers in the last part stroke and compensating for any deviation from the desired value for the last part stroke when instructing the linear actuator to move the next part stroke, in particular when the last part stroke fell short due to the dosing plungers reaching the end of their stroke.

In an embodiment, the average speed of the dosing plungers during the last stroke performed is determined by comparing the activation time of the last part stroke with the achieved part stroke length and the activation time for the next part stroke is based on the determined average speed of the dosing plungers during last part stroke.

In an embodiment the method further comprises adjusting the length of a part stroke of the dosing plungers in response to engine operating conditions.

In an embodiment the method further comprises adjusting the length of a part stroke of the dosing plungers for each injection event.

In an embodiment of the method the cylinder lubrication device comprises hydraulic valve connected to the first hydraulic linear actuator and connected to the second hydraulic linear actuator and the method comprises selectively connect the first hydraulic linear actuator to a source of hydraulic pressure and configured to selectively connect the second hydraulic linear actuator to the source of hydraulic pressure.

In an embodiment the method further comprises pressurizing the first hydraulic linear actuator to move the dosing plungers over a fraction of its total stroke length, and pressurizing the second hydraulic linear actuator to return the plungers only when the dosing plungers have reached their end position (E).

In an embodiment of the method the hydraulic valve is an on/off type valve and the method comprises controlling the part stroke of the dosing plungers by controlling the length of the period during which the on/off valve connects the first hydraulic linear actuator to the source of hydraulic pressure.

In an embodiment the method comprises controlling the hydraulic on/off valve such that the plungers move with continually variable length strokes that are adjusted for each injection event to the engine operating conditions and by providing a time pulse to the on/off valve to open the on/off valve for a predetermined time corresponding to a predetermined dose of lubrication fluid.

The object above is also achieved by providing a cylinder lubrication device for a large slow running two-stroke diesel multi-cylinder engine having in each cylinder a reciprocating piston with piston rings that slide on the inner surface of the cylinder liners whereby the cylinder lubrication device provides the inner surface of the cylinder liners with a precisely dosed quantity of cylinder lubrication oil per reciprocation or per number of reciprocations of the cylinder via a plurality of injection points that are distributed at equal level around the circumference of a cylinder, the cylinder lubrication device having a plurality of piston pumps, each piston pump having a dosing plunger slidably movable in the dosing cylinder, a common drive including a linear actuator for driving all of the dosing plungers simultaneously, and a position sensor arranged to detect the position of the common drive or of the dosing plungers, the method comprising: determining a desired length of the injection stroke, instructing the linear actuator to move the dosing plungers simultaneously over the desired length of the injection stroke, thereafter, moving the dosing plungers simultaneously back in a refill stroke, determining the actual length of the performed injection stroke with the information from the position sensor, and compensating for any deviation from the desired value for the previous injection stroke when determining the desired length for next injection stroke.

By measuring the last injection stroke and compensating when instructing the next injection stroke precision is increased and consumption of the precious cylinder lubrication oil can be reduced.

In the above method the common drive can be driven by resilient member in the refill stroke.

The cylinder lubrication device may be adapted with any of the features according to any of the embodiments of the engine mentioned above. Further, the cylinder lubrication device may perform any of the embodiments of the method described above.

Further objects, features, advantages and properties of the engine, the lubrication device and the method according to the invention will become apparent from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the description, the invention will be explained in more detail with reference to the exemplary embodiments shown in the drawings, in which:

- figure 1, in a perspective view, shows a cylinder lubrication device according to an embodiment of the present invention,
- figure 2a shows a section through the cylinder lubrication device shown in figure 1,
- figure 2b shows a cross-section through the cylinder lubrication device shown in figure 1,
- figure 3 shows another section through the cylinder lubrication device shown in figure 1, the section being perpendicular to the section shown in Fig. 2,
- figure 4a shows a detailed view of a portion of the cylinder lubrication device shown in Fig. 3 with the dosing plungers in an intermediate position,
- figure 4b shows a detailed view of a portion of the cylinder lubrication device shown in Fig. 3 with the

dosing plungers in their start position and interrupted lines show a number of random part strokes,

- figure 4c shows a detailed view of a portion of the cylinder lubrication device shown in Fig. 3 with the dosing plungers in their end position,
- figure 5, in a principle sketch, shows a section through a cylinder lubrication device according to an embodiment of the present invention,
- figure 6, in a diagrammatic depiction, shows a section through a cylinder of a large two-stroke diesel engine with cross-heads,
- figures 7 shows a large two stroke diesel engine according to an example embodiment of the invention,
- figure 8 shows another example embodiment of the cylinder lubrication device, and
- figure 9 is a graph illustrating the relation between stroke length and time for a series of lubrication fluid injections.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the following detailed description of the engine, the cylinder lubrication device and the method of controlling a lubrication fluid injection into an engine cylinder according to the invention will be described by the example embodiments.

The invention relates to an engine cylinder lubrication device 1 for a large two-stroke diesel engine 100 of the crosshead type, which may constitute the main propulsion system of a ship or a stationary electric power producing engine. Referring to Fig. 6 and 7, the engine 100 has multiple cylinders 110 (a section of one cylinder is shown in Fig. 6), typically three to fourteen cylinders 110, arranged in line, but may have other layouts or number of cylinders 110. Each cylinder 110 is provided with a cylinder liner 111 forming an inner surface of the cylinders 110. In large two-stroke engines 100 a cylinder inner diameter (the bore) is typically in the interval from 250 mm to 1200 mm. A stroke length of a reciprocating piston 120, slideably arranged in the cylinder liner 111, is typically in the range of 800 to 3000 mm. Thus, the surface of the cylinder liner 111 that needs to be lubricated may be several square meters. The pistons 120 are connected to a crosshead 124 via a piston rod 126. The crossheads 124 are connected to the crankshaft 130 via connection rods 128.

The reciprocating piston 120 is typically provided with 3-5 pressure preserving piston rings 121 that slide on the inner surface of the cylinder liner 111. In Fig. 6 a piston with three piston rings 121 is shown. It is an object of the cylinder lubrication system of the engine to provide and maintain a lubricant film on the inner surface of the liner 111, to lower the friction between the piston rings 121 and the inner surface of the liner 111, and to protect the inner surface of the cylinder liner from chemically aggressive substances in the combustion gases.

Cylinder lubrication fluid, such as lubrication oil with alkaline additives to neutralize the sulfuric acid formed during combustion of HFO in the combustion chamber of the cylinders 110, is applied via cylinder liner lubrication fluid points or quills 112 formed through the cylinder liner 111. The cylinder liner lubrication fluid quills or injection points 112, may be simple outlets (holes) or they may be formed with a nozzle or injector, or in other ways known in the art and in en embodiment the quills 112 are provided with non-return valves that prevent exhaust gases from entering in the cylinder lubrication oil. Typically, there are several cylinder liner lubrication fluid quills 112 formed in a cylinder liner 111, such as 4-12, or 4-20, the cylinder liner lubrication fluid quills 112 being distributed equally spaced around the liner 111 and arrange at equal height to ensure equal application of the lubrication fluid.

In case certain areas of the cylinder 110 are more or less prone to wear, the concentration of the cylinder liner lubrication fluid quills 112 corresponding to that area, may be increased or decreased, respectively. After injection, the injected lubrication fluid is distributed on the liner 111 by the piston rings 121.

The construction and operation of a large two-stroke diesel engine with crossheads is as such well-known and should not require further explanation in the present context.

Fig. 1 shows an example embodiment of a cylinder lubrication device 1. The cylinder lubrication device 1 comprises a housing 10 and an actuation device 40 coupled to housing 10.

Figs. 2a,2b,3,4a - 4c in sectional views, show details of the cylinder lubrication device 1 of Fig. 1. A number of identical single acting piston pumps are disposed in the housing 10. Each piston pump includes a dosing cylinder 29 that is formed in the housing 10. In the section chosen in Fig. 2 the dosing cylinders 29 cannot be seen. In the section chosen in Figs. 3 and 4, one dosing cylinder 29 is visible. Injection chambers 20 are formed in front of the dosing plungers 30.

The piston pumps are preferably arranged in a circle (seen in a section perpendicular to an elongate axis of the dosing cylinders 29), but this is merely a preferred arrangement and other arrangements such as along a straight- or curved line or in a rectangular arraignment can just as well be used.

In the embodiment shown in Figs. 1,2a,2b,3,4a – 4c there are ten piston pumps, which in Fig. 1 is indicated by ten injection outlets 21 formed at the top of the housing 10. In a preferred embodiment there are 10 piston pumps, but there may be any other number e.g. from 2 to 12, or even more.

Referring now to Fig. 5 showing a conceptual sketch of the cylinder lubrication device 1, two piston pumps with each a dosing cylinder 29 are visible. In each dosing cylinder, a dosing plunger 30 is slidably received. The dosing plunger 30 is configured to expel a volume of lubrication fluid from an injection chamber 20 in an injection event into an engine cylinder 110, and to refill the injection chamber 20 with a volume of lubrication fluid. Thus, the dosing plunger 30 is arranged to form a seal (at least at a plunger head 30’) with the inner walls of the dosing cylinder 29, and is slideably moveable in the dosing cylinder 29.

All of the dosing plungers 30 are connected at their one end to a plunger connector 31 that includes a trust plate and a flange with recesses in which the ends of the dosing plungers 30 received, so that the plunger connector forms part of a common drive that can both push the dosing plungers 31 for an injection stroke and pull the dosing plungers for a suction stroke. The plunger connector 31 is arranged in a connector chamber 32 formed in the housing 10 in extension of the injection chambers 20. Sliding of the plunger connector 31 will thus cause all the plungers 30 to slide simultaneously inside their respective dosing cylinders 20.

The plunger connector 31 is also connected to a first piston 41 slidably arranged cylinder together defining a first pressure chamber 35, thereby forming a first linear actuator. The first pressure chamber 35 is in fluid connection with a valve means that may be a hydraulic on-off valve 40, through a first activation conduit 60 (see Fig. 2). The first activation conduit 60 has an opening 60’ into the first pressure chamber 35, see Fig. 5.

Movement of first piston 41 relative to the housing 10 thus causes movement of the plunger connector 31 in the connector chamber 32, which again will cause simultaneous movement of the dosing plungers 30 in the respective dosing cylinders 29.

The plunger connector 31 may be a plate shaped element, but may have other configurations, such as arms (not shown) extending from the first piston 41.

The injection chambers 20 are in fluid communication with an injection outlet 21 formed on an outer wall of the housing 10 through injection passages from the injection chambers 20 to the injection outlets 21.

In the embodiment shown in Fig. 5, these injection passages each have a first conduit 11 forming an exit or outlet from the injection chamber 20. The first conduit 11 may be formed in an end wall of the injection chamber 20 as shown, or it may be formed in the sidewall of the injection chamber 20 at the end of the chamber opposite the connector chamber 32. The first conduits 11 connect the injection chambers 20 with respective intermediary conduits 12.

In the shown embodiment, the intermediary conduits 12 are transversely oriented in the housing 10 with respect to the longitudinal axis of the injections chambers 20. The intermediary conduits 12 (and the first conduits 11) serve the dual purpose of conducting lubrication oil to and from the injection chambers 20, as will be described below.

Second conduits 13 connect the respective intermediary conduits 12 with respective injection conduits 14, which form connections to respective injection outlets 21.

One way valves 22 are arranged in the injection conduits 14, in second conduits 13 or there between, in order to prevent a backflow of material from the cylinders of the engine. Thus, one way valves 22 only allows a flow towards the injection outlets 21.

The one way valves 22 may be formed in chambers 22’ formed between the second conduits 13 and the injection conduits 14, or in the second conduits 13 or in the injection conduits 14.

Thus each injection passage, in the embodiment shown in Fig. 2, comprises a first conduit 11, an intermediary conduit 12, a second conduit 13, and an injection conduit 14.

Housing 10, in Fig. 2, is shown as being formed as a single entity or component, but may be formed by several component parts. The above mentioned chambers, passages and conduits 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 may be formed in the housing as inmolded passageways or as bores. But, they may also be formed by and assembly of suitable tubing, piping, cylinders or the like.

The injection outlets 21 are connectable to cylinder liner lubrication fluid points/quills 112 formed in the cylinder liners 111 by a suitable piping (not shown).

The injection chambers 20 are fed with lubrication fluid via lubrication fluid supply passages. In the embodiment shown in Fig. 5, these supply passages for lubrication fluid starts with an inlet 15 common to all injection chambers 20, and formed in the housing 10. The inlet 15 opens into an inlet conduit 16. Through a third conduit 17, the inlet conduit 16 is in fluid communication with an inlet conduit ring 18.

The inlet conduit ring 18 is formed in the housing 10 in a plane transverse to the longitudinal axes of the injection chambers 20, and it is a ring-shaped conduit.

In other embodiments (not shown) there may be two-four inlets 15 and corresponding inlet conduits 16 leading to an inlet conduit ring 18.

Fourth conduits 19 connect the inlet conduit ring 18 to each of the above mentioned intermediary conduits 12, which are again connected to respective injection chambers 20 through the first conduits 11.

One way valves 23 are arranged in the supply passages between the fourth conduits 19 and the intermediary conduits 12 in order to ensure that lubrication fluid does not flow back from the intermediary conduits 12 to the inlet conduit ring 18. The one way valves 23 may be formed in the fourth conduits 19 or in chambers 23’ formed between the fourth conduits 19 and the inlet conduit ring 18.

Thus each of the supply passages in the shown embodiment comprises a first conduit 11, an intermediary conduit 12, a fourth conduit 19 and the common inlet conduit ring 18, the common third conduit 17, the inlet conduit 16 and the common inlet 15. Here common means common to all the supply passages.

As also mentioned above, the intermediary conduits 12 and the first conduits 11 serve the dual purpose of conducting lubrication oil to and from the injection chambers 20, and thus forms part of both the respective supply passages as well as the respective injection passages. This will be described further below.

The inlet 15 of the lubrication fluid supply passage is connected to a pressurized source of lubrication fluid, e.g. a lubricating oil tank. This is preferably pressurized by a high pressure positive displacement system, in order to provide an equal supply of lubrication fluid to each injection chamber 20, and to provide a safety margin against clogging of the individual injection chambers 20 and the supply passages thereto.

The one way valves 22 formed in the injection passages, and the one way valves 23 formed in the supply passages may be of the ball valve type. Alternatively, electronically or hydraulically controlled shut-off valves or on/off-valves may be used instead of the one-way valves.

The housing 10 supports the hydraulic on/off valve 40. The hydraulic on/off valve 40 is configured for filling the first pressure chamber 35 with a hydraulic fluid thereby acting on first piston 41. Fig. 2a illustrates how the hydraulic control valve 40 is connected to a source of hydraulic pressure P and to tank T.

The plunger connector 31 is also connected to a second piston 46 slideably arranged in a second cylinder 36 thereby defined a second pressure chamber 37, thus forming the second linear hydraulic actuator. The second pressure chamber 37 is in fluid connection with the hydraulic on/off valve 40. Through a second activation conduit 61 (see Fig. 2). The second activation conduit 61 has an opening 61’ into the second pressure chamber 37, see Fig. 5.

Movement of the first- and second pistons 41, 46 relative to the housing 10 causes movement of the plunger connector 31 in the connector chamber 32, which again will cause simultaneous movement of the plungers 30 in the respective injection chambers 20. The first and second pressure chambers 35, 36 are arranged on opposite sides of the connector chamber 32. Similarly, the first and second pistons 41, 46 are arranged on opposite sides of the plunger connector 31. Each of the first and second pistons 41, 46 are sealing against inner walls of first and second pressure chambers 35, 36. Thereby, by alternatingly pressurizing the first and second pressure chambers 35, 36, the plunger connector 31 with the plungers 30 may be moved in opposite directions relative to the housing 10. This function of the cylinder lubrication device 1 will be described in more detail in the following. Pressurizing the first pressure chamber whilst connecting the second pressure chamber to tank T causes the dosing plungers to move in the injection direction and pressurizing the second pressure chamber whilst connecting the first pressure chamber to tank causes the dosing plunger to move in the return/refill direction.

In one extreme position, the plungers 30 of the injection chambers 20 are in their most extended position (E), i.e. they are situated at their bottom position such that plunger heads 30’ of the plungers 30 are adjacent to the first conduit 11 i.e. an inlet/outlet of the injection chamber 20.

In order to fill the injection chambers 20 with lubrication fluid, the hydraulic valve 40 pressurizes the second pressure chamber 36, and connects the firs pressure chamber 35 to tank and thereby the plungers 30 (via plunger connector 31) are moved in a direction away from the first conduit 11, i.e. downwards in Fig. 5 for a return/aspiration/refill stroke. This will provide a reduction in pressure in the injection chambers 20. The one way valves 22 in the injection passage will prevent lubrication fluid (or other materials) to enter into the intermediary conduit 12 from the injection conduit 14 and the injection outlets. In order to compensate the pressure reduction in the injection chamber 20, lubrication fluid from the pressurized lubrication fluid source will start to flow from the inlet 15 through the inlet conduit 16 and the third conduit 17 and enter into the inlet conduit ring 18. From the inlet conduit ring 18 the lubrication fluid will flow through the one way valves 23 in the supply passage and the fourth conduits 19 into the intermediary conduits 18 and the first conduits 11 into the injection chambers 20.

Thus, the inlet conduit ring 18 serves to distribute lubrication fluid to all injection chambers 20 from the inlet 15.

Preferably, the length of the connector chamber 32 is arranged to correspond to the length of the injection chambers 20, such that when the plunger connector 31 is in its most retraced position (abutting a rear wall 33 of the connector chamber 32) the plunger head 30’ is still located in the injection chamber 20, and forming a tight seal with the inner wall of the injection chamber 20.

When the dosing plungers 30 have been retracted to their start position S and the injection chamber 20 has reached is maximum volume, an injection event of lubrication fluid may be initiated by actuating the first piston 41 (by the hydraulic valve connecting the first pressure chamber 35 to a source of pressure P and connecting the second pressure chamber 36 to tank) to start a movement of the dosing plungers 30 towards the first conduits 11, thus building up pressure in the injection chambers 20.

This will expel the lubrication fluid located in the injection chambers 20. Thus, lubrication fluid will flow through the first conduits 11 and the intermediary conduits 12.

Because the one way valves 23 in the supply passages prevents flow towards the inlet conduit ring 18 and the inlet 15, the lubrication fluid can only flow through the second conduits 13 through the one way valves 22 in the injection passages, and through the injection conduits 14, and out through the injection outlets 21. From there the lubrication fluid is led via a suitable piping to the cylinder liner lubrication fluid points/quills 112. Then another cycle of filling the injection chambers 20 may begin.

The hydraulic valve 40 is connectable to an electronic control unit 50. This electronic control unit 50 may in an embodiment be incorporated in the cylinder lubrication device 1, either in the housing 10 or in the actuation device 40. The electronic control unit 50 is connectable to either a set of sensors or some other control/sensor system of the engine 100 that can provide information about the position of the engine piston 120, e.g. via a signal indicating the position of the crankshaft 130, and possibly other engine operation conditions. Some of said sensors may be situated inside the engine cylinder 110, or may be registering the position of a crankshaft of the engine 100.

In another embodiment the electronic control unit 50 is an engine control system (ECS). Engine control systems are already adapted to receive information about the engine piston 120 position and other engine operation conditions, and therefore can be constructed to control a cylinder lubrication device 1 in accordance therewith, e.g. based on information on the engine piston top dead center (TDC), crankshaft position, the engine speed in RPM, engine load, actual fuel consumption or other engine or individual cylinder operating conditions, such as the sulfur content of the HFO at a fuel inlet valve or sulfuric acid concentration in the cylinders, the wear of a cylinder (based on signals from sensors in the cylinders), cylinder liner 111 temperature, lubrication fluid build-up in a cylinder, alkaline deposit build up, lubrication oil BM, engine load, etc. A basic rule is that the cylinder oil dosage should be proportional to the sulfur percentage in the fuel and the cylinder oil dosage should be proportional to the engine load. Since the engine load is essentially proportional to the amount of fuel entering the cylinders. The amount of fuel injected is also controlled by electronic control unit 50 and this information is therefore available for determining the required cylinder oil dosage. If the engine electronic control unit and the cylinder lubrication electronic control units are separate units the information on the engine load, on the amount of fuel injected or even the required cylinder oil dose can be communicated from the engine electronic control unit to the cylinder lubrication electronic control unit.

The amount of cylinder lubrication oil needed per revolution depends as stated on the engine load and the sulfur content of the fuel, but is quite accurately known for a specific engine, specific load and specific fuel sulfur content. These data are known from calculations and from tests. Thus, the maximum dosage per revolution at maximum load and the highest fuel sulfur content is well known and can be used to dimension the full stroke length and diameter of the dosing plungers 30 of the piston pumps so that even in these maximum cylinder oil consumption conditions there are several part strokes Ps possible before the full stroke of the dosing plungers 30 is reached. If e.g. at full engine load and high fuel sulfur content 100 cc. cylinder lubrication oil is used per stroke it would be required that the displacement volume of the piston pumps is at least 2 to 3 times larger, i.e. at least 250cc, preferably at least 5 time larger, i.e. at least 500cc. Preferably the diameter of the dosing plungers 30 is chosen such that the resulting full stroke is suitable for accurate operation with the linear actuator that is used.

The electronic control unit 50 may thus be connected to and configured for controlling the cylinder lubrication devices 1 of a portion or all of the cylinders 110 of the engine 100.

The actuation device 40 or the cylinder lubrication device 1 housing 10 is equipped with a position sensor 44 connected to the above mentioned electronic control unit 50, to provide the electronic control unit with a signal 51 carrying information on the position of the plungers 30 in the injection chambers 20, e.g. by measuring the position of the plungers 30 themselves, the plunger heads 30’, the first or second pistons 41, 46, or the plunger connector 32. This information is used to improve the precision of the injections, the electronic control unit 50 being connected to and configured to provide control signals 52 to the hydraulic valve 40.

In a preferred embodiment the first piston 41 is provided with an extension 42, the extension 42 being in the form of a rod, having a diameter or cross sectional area smaller than the diameter or cross-sectional area of the first piston 41. The extension 42 extends into a position measuring device 70 including a position sensor 44. Thereby the positions of the plungers 30 in the injection chambers 20 are measured by the position of the extension 42 in the position measuring device 70.

Preferably, one cylinder lubrication device 1 serves one cylinder of the engine, the number of injection chamber 20 being adapted to the number of cylinder liner lubrication fluid points/quills 112, and depending on the size of the cylinders. Alternatively, a single engine cylinder may be served by more than one cylinder lubrication device 1.

The electronic control unit 50 is configured to provide at least one injection of lubrication fluid per engine cycle. An injection is preferably provided between two piston rings 121, when the engine piston 120 passes the cylinder liner lubrication quills/point 112 in at least one direction.

In an embodiment the electronic control unit 50 is configured to provide at least one injection of lubrication fluid between each of two pairs of piston rings 121, when the engine piston 120 passes the cylinder liner lubrication point/quill 112 in at least one direction. In an embodiment the electronic control unit 50 is configured to provide at least one injection of lubrication fluid between each pairs of piston rings 121, when the engine piston 120 passes the cylinder liner lubrication point 112 in at least one direction. In a further embodiment applicable to any of the embodiments described directly above, the electronic control unit 50 is configured to provide at least one injection of lubrication fluid for each passage of the engine's piston (up/down). This is applicable in embodiments where the cylinder liner lubrication point/quill 112 is arranged in the cylinder liner 111 at a position where the engine's piston passes the cylinder liner lubrication point/quill 112 twice during a revolution of the combustion cycle.

In an alternative embodiment the cylinder liner lubrication point/quill 112 is arranged in the cylinder liner, such that the cylinder liner lubrication point 112 is flush with a space between the lowest and the second to lowest piston rings 121 (the lowest pair of piston rings) when the piston 120 is at top dead center.

Above, a preferred lubrication device 1 has been described. However, other types of lubrication devices may also be used in connection with the invention. The lubrication device in general must have at least one injection chamber 20 with a plunger. The injection chamber must have a known volume or at least a known diameter (or cross sectional section). Means for determining the position of the plunger in the injection chamber must be provided.

The lubricating device 1 for engine cylinder lubrication preferably comprises double acting hydraulic pistons or a first and second piston driving a plunger connector 31 or trust plate for activating a number of lubricator-pumps, such as plungers 30 provided in injection chambers 20. The lubricator pumps are arranged for feeding cylinder oil/lubricator fluid to individual lubricating quills 112 mounted in the cylinder liner 111 of a an engine cylinder 112.

The individual lubricator pumps consisting of a plunger 30, a barrel 29 /injection chamber 20, a suction valve or a suction gab and a second non-return valve at the delivery port of the pump.

The cylinder lubrication device 1 shown in Figs. 1,2a,2b,3,4a,4b,4c differs from the one shown in Fig. 5 in the arrangement of the channels for filling and emptying (injecting) the lubrication fluid in the barrels/injection chambers 20. The device in figs. 1-4 also has a common inlet port (not shown).

The hydraulic actuator pistons (first and second pistons 41, 46) are powered by oil under pressure through a control valve 40, enabling the actuator pistons and the plunger connector 31 (may also be called trust plate) and the plungers 30 to be moved in either direction and be positioned or stopped at any position relative to the full stroke of the plungers 30.

Preferably, the pressure for actuating the first and second pistons 41, 46 corresponds to the pressure of the general hydraulic system of the engine. The actuator piston (first and second pistons 41, 46) sizes are adjusted accordingly.

The position of the actuator pistons (first and second pistons 41, 46) and/or the plungers 30 is measured by a position sensor 44.

The lubricating device 1 is preferably controlled by an on/off valve 40, and the on/off valve 40 is controlled by an electronic control unit 50 (electronic control system/control system).

The control system 50 activates the control valve 40 in the time domain (a number of milliseconds (mS)). The relationship between the activation time and stroke length is monotonic, i.e, a longer activation time gives a longer stroke but the relation is not linear. This means that dividing a lubricating pulse into two halves in ms-regiment will give a lower lubrication oil dose than one pulse with the length of the two halves.

When the lubricating device 1 is calibrated the lubricating device 1 is controlled with set point activation with a rate shaping profile according to the description below.

The system and lubricating device 1 always uses the full stroke or nearly the full stroke of the dosing plungers 30 in order to measure the injected cylinder oil amount precisely by counting the number of full strokes over time. However the full stroke is divided in several small part strokes Ps, i.e. portions of the full stroke for each cylinder oil supply event. By utilizing this principle, the overall efficiency of the cylinder lubrication device is increased and wear is better distributed. The electronic control unit 50 calculates the number of full strokes performed in order to sum up the delivered oil amount over time. The dosing plungers are returned to their start position (fully retracted position S) only after the full stroke or almost the full stroke is performed, i.e. when necessary. In an embodiment where the control of the movement of the dosing plungers is carried out in an accurate closed loop control the full stroke of the dosing pistons can be utilized, i.e. even if the remaining stroke that is available until the end position E is smaller than the required length of the next part stroke. Such an accurate control can compensate for the shortfall of a part stroke completely up to the end position (E) in a next stroke. In an embodiment with a less accurate control, i.e. a control system based on a time pulse for activating and on/off type valve hydraulic the last portion of the full stroke cannot be used if its length is less than the desired length for the next part stroke. In such a case, the controller will command the dosing plungers to return to the start position S and initiate the next part stroke from the start position.

Full stroke is detected by the position sensor 44 or a separate full stroke sensor 45.

By always using the full (or most of the full) stroke of the pump cylinder, the wear is levelled out over the entire running surface of the injection chambers 20, thus increasing the lifetime of the pumps.

The lubrication fluid/cylinder oil can be injected at any given crank angle, i.e. at a pre-determined crank angle, according to an engine mounted angle sensor, but preferably at the crank angle that corresponds to the piston 120 concerned being in front of the injection points/ quills 111 so that the cylinder lubrication oil is injected between the piston rings 121.

Injection volume for each individual injection can be adjusted, and the injection period (mS) can be adjusted, for each injection.

The diameter of the dosing cylinders 29 (and equally of the dosing plungers 30) and the length of the full stroke is preferably chosen such that a fully filled injection chamber 20 contains enough lubrication fluid/cylinder oil for a plurality of part injection strokes to the engine piston 120. The exact number of part injection stroked covered depends on engine load and cylinder condition. A new cylinder liner requires substantially more lubricating oil during a limited running in period compared to the following normal running conditions and therefore the volume of the injection chamber for a corresponding to a full stroke length is determined by the lubrication requirements during running-in of the cylinder liner so that even during running in of the cylinder liner the full stroke can contain more than necessary part strokes Ps.)

The dosing plungers 30 are not repositioned to their extreme rearward position (i.e. the injection chambers 20 are not filled/refilled) until the maximum stroke length of the plungers 30 plus next dose, has been reached or exceeds the maximum. Thereby, also energy is preserved.

In general, the cylinder lubrication device 1 according to the above described embodiments operates by the following principle of operation: The cylinder lubrication device 1 consists of a double acting hydraulic piston or pistons 41, 46 driving a plunger connector 31 (trust plate) activating a number of piston pumps comprising the above mentioned dosing cylinders 29

20 with dosing plungers 30, feeding cylinder oil to individual lubricating quills 112 mounted in the cylinder liner 111. The double acting linear hydraulic actuators, the plunger connector 31 and dosing plungers 30 are coupled mechanically by interlocking.

The individual piston pumps comprise a dosing plunger 30, a dosing cylinder 29, a suction valve or a suction gap and a non-return valve at the delivery port of the pump.

The hydraulic actuator pistons or pistons 41, 46 is/are powered by oil under pressure thru one or more control valves, enabling the actuator piston 41, 46 / plunger connector 31/ dosing plungers 30 to be moved in either direction and be positioned or stopped at any position of the full stroke.

The actuator oil pressure can be fixed or variable according to engine designer’s specification and engine operating conditions.

The position of either the actuator piston 41, 46 or the plungers 30 is measured by a position sensor 44. In the embodiment shown in Fig 1-4 the sensor 44 is arranged at an extension 42 of the actuator piston 41.

The cylinder lubrication device 1 is controlled by an adaptive cyclic feedback system. This system activates the control valve in time domain (a number of milliseconds (ms)). An activation of the actuator piston 41, 46 forces the plungers 30 to perform a stroke. The stroke is followed by a measurement of the actually performed stroke when the actuator piston 41, 46 has stopped its movement.

Based on the measured stroke length the control mechanism calculates the next activation time pulse length taking the measurement of the length of the previous part stroke or strokes into account. The control mechanism takes the length of the next part stroke into account to determine if it is necessary to return to the start position.

The cylinder lubrication device 1 always uses the full stroke of the piston 41, 46/ dosing plungers 30 in order to measure the injected cylinder oil amount precisely by summarizing the part and full stroke lengths over time. However the full stroke can be divided in several small portions of the full stroke to reduce the oil amount per activation. All injections both main (full strokes) as well as the partial activations are timed according to the crank angle of the engine. The electronic control unit 50 summarizes the number and length of part strokes in order to give a precisely measured lubrication oil amount over time.

The actuator pistons 41,46 is returned to their start position after the full stroke is performed.

A full stroke of the plungers 30 in the dosing cylinders 29 is detected by the position sensor 44 or a separate full stroke sensor 45.

By always using as much a possible of the full stroke of the pump cylinder (plungers 30 in barrels 20) the wear of the piston pumps is leveled out over the entire running surface of the barrels 20 of the piston pumps. Thereby the lifetime of the piston pumps is increased.

The cylinder lubrication oil can be injected at any desired crank angle, and the individual oil injection timing can be adjusted continuous variable according to the engine designer's specification and engine operation conditions.

The cylinder lubrication device 1 preferably follows the following working cycle:

At start-up the system performs a calibration stroke to determine maximum and minimum values from the position sensor according to the mechanical end stops of the plungers relative to the barrel in which they are arranged displaceable in a longitudinal direction.

Then, the control unit 50 moves the actuator piston 41, 46 to its start position.

The electronic control unit 50 determines the desired dose/quantity of cylinder lubrication oil that is to be injected in the next injection event, i.e. determines the length of the next desired part stroke of the dosing plungers 30.

The electronic control unit 50 orders a time pulse or valve activation time (i.e. by calculating the expected time that the control valve 40 needs to be open in order to move the dosing plungers 30 a desired length in the dosing cylinders 29, which is equivalent of a desired volume of cylinder lubrication oil). Then, the electronic control unit 50 activates the control valve 40 at the predetermined crank angle and the actuator piston 41, 46 moves a part stroke forward towards the foremost mechanical stop trust. The electronic control unit 50 compensates in a following part stroke for a shortfall in the length of a part stroke..

After the actuator piston movement has stopped the position sensor 44 measures the actual position of the actuator piston 41 (or the plungers 30).

A new time pulse is calculated based on the previous measurement, i.e. any shortfall or excess of the last part stroke due to changes pressures and viscosity of either- or both the cylinder lubrication oil and the hydraulic oil is compensated for by the electronic control unit 50 in the following stroke.

The new time pulse is activating the control valve 40 at the predetermined crank angle and the actuator piston 41, 46 is moved forward again for the length of a part stroke from its present position followed by another position measurement.

The electronic control unit 50 keeps track of the remaining available stroke length of the plungers 30 in the dosing cylinders 29, and orders the actuator piston 41, 46 to return to its start position when the next part stroke the remaining stroke length available up to the end position e is less than the desired length of the next part stroke.

In the case that the last stroke, before contacting the mechanical end stop, is calculated to be lager that the remaining possible stroke the injection chamber 20 is emptied against the mechanical stop and the oil amount needed to complete the lubrication is added in the next part stroke/injection.

In another embodiment, in the case where the next part stroke, is calculated to be lager that the remaining possible stroke the injection chamber 20 is emptied against the mechanical stop, the dosing plungers are returned to the start position and the oil amount needed to complete the lubrication is added in the next part stroke.

The dosing plungers 30 are not repositioned to their extreme rearward position (i.e. the injection chambers 20 are not filled/refilled) until the maximum stroke length of the plungers 30 has been reached. Thereby, also energy is preserved.

The two hydraulic actuators or double acting linear hydraulic actuator is powered by oil under pressure through the control valve, enabling the linear actuator/trust plate/dosing plungers to be moved in either direction and be positioned or stopped at any position of the full stroke.

Fig. 8 shows another embodiment of cylinder lubrication device and method according the invention that is essentially identical to the embodiment described above, except that the hydraulic valve is proportional 4/3-way valve 140 and that the operation is different as explained below.

The lubrication fluid/cylinder oil can be injected in accordance with the actual need. With the proportional hydraulic valve 140 the operation can include:

- Rate shaping of the lubrication fluid/cylinder oil injections in one or multiple portions per revolution of the engine, or with intermittent.
- Injection volume for each individual injection can be adjusted, and the injection period (mS) can be adjusted, for each injection.

In this embodiment the signal of the position sensor is used in a feedback control loop and the position of the proportional hydraulic valve 140 is adjusted accordingly by the electronic control unit so that the speed and position of the linear hydraulic actuator is continuously and exactly controlled with a closed loop control method. Thus, the speed and of dosing the cylinder lubrication oil and the amount of the dose of cylinder lubrication oil can be accurately and instantaneously controlled.

With reference to Fig. 9 this will be explained in further detail. For every reciprocation of the piston 120 of a cylinder 110, a series of injections may be performed. Thus the desired volume s_D to be injected per revolution is

$s_D = S_1 + S_2 + \ldots + s_n$

The time t1, t2, t3, …, tn of an individual injection and the periods of the individual injections in a revolution is variable.

Thus, in Fig. 7, the pitch of the graph for the injection profile, corresponding to the speed v of an injection, v= ds/dt is variable.

The desired volume sD = S1 + S2 + … + sn , e.g. S1 + S2 (two injections) are performed during a passage of the piston. Thus, the embodiment with the proportional hydraulic valve allows for a single lubrication event to be divided into several part events, i.e. during one passage of the piston there can be performed two or more lubrication oil injections.

According to another embodiment (not shown) the actuator driving the common drive is a double acting linear actuator powered by an electric drive motor. This embodiment can use a linear double acting electric drive motor or a reversible rotary electric drive motor that is coupled to a mechanism that converts rotation of the reversible rotary electric drive motor into a linear movement.

For all the embodiments above it is applies that an actuator is used for the return stroke so as to be able to return the dosing plungers to their start position S relatively quick, i.e. quicker than when using resilient means such as a helical spring.

According to another embodiment (not shown) a method for for operating a cylinder lubrication device for a large slow running two-stroke diesel multi-cylinder engine having is disclosed in which the dosing plungers return to their start position and refill their pump chamber after each variable length stroke. In this embodiment the cylinder lubrication device is substantially identical to the cylinder lubrication device shown above, except that the length of the stroke of the dosing plunger and the diameter of the dosing plunger is large enough for a plurality of partial strokes, i.e. the maximum displacement of the dosing pumps is roughly equal to the maximum single dose required for the engine concerned.

The cylinder lubrication device will have a plurality of piston pumps, each piston pump having a dosing plunger slidably movable in the dosing cylinder, a common drive including a linear actuator for driving all of the dosing plungers simultaneously and a position sensor 44 arranged to detect the position of the common drive or of the dosing plungers 30. The method comprises: determining a desired length of the injection stroke, instructing the linear actuator to move the dosing plungers (30) simultaneously over the desired length of the injection stroke, thereafter, moving the dosing plungers simultaneously back in a refill stroke, determining the actual length of the performed injection stroke with the information from the position sensor, and compensating for any deviation from the desired value for the previous injection stroke when determining the desired length for next injection stroke. In this the common drive may be driven by a resilient member in the refill stroke.

Although the embodiments above illustrate the first linear hydraulic actuator as a single cylinder piston unit, it is understood that the first hydraulic actuator may instead comprise a plurality of cooperating cylinder-piston units. The same applies to the second linear hydraulic actuator, it may comprise several cylinder/piston units.

For all embodiments above the capacity of the assembled lubricators 1 should equal or exceed the demands of the engine 100.

Consequently, the invention provides a great variety of possible designs and adaptation of a lubrication system.

The teaching of this invention has numerous advantages. Different embodiments or implementations may yield one or more of the following advantages. It should be noted that this is not an exhaustive list and there may be other advantages which are not described herein. One advantage of the teaching of this application is that it provides a great flexibility in designing and operating a lubrication system.

Although the teaching of this application has been described in detail for purpose of illustration, it is understood that such detail is solely for that purpose, and variations can be made therein by those skilled in the art without departing from the scope of the teaching of this application.

The term "comprising" as used in the claims does not exclude other elements or steps. The term "a" or "an" as used in the claims does not exclude a plurality. The single processor or other unit may fulfill the functions of several means recited in the claims.

PATENTKRAV

1. Anordning (1) til smøring af cylindre til en stor, langsomt kørende, flercylindret, totaktsdieselmotor, hvilken stor, langsomt kørende, flercylindret, totaktsdieselmotor i hver cylinder (110) har et frem- og tilbagegående stempel (120) med stempelringe (121), der glider på den indvendige overflade af cylinderforingerne (111), hvorved anordningen (1) til cylindersmøring er konfigureret til at forsyne den indvendige overflade af cylinderforingerne med en præcist doseret mængde fluid til cylindersmøring i forhold til stemplets (120) frem- og tilbagegående bevægelser via en flerhed af indsprøjtningspunkter (112), der er fordelt i periferien af en cylinder (110), hvilken anordning (1) til smøring af cylindre omfatter:

- en flerhed af stempelpumper, hvor hver stempelpumpe har et doseringsstempel (30), der kan bevæge sig glidende i en doseringscylinder (20) mellem en startposition(S) og en slutposition (E),

- et fælles drev (31), der indbefatter en lineær aktuator (41, 46) til at drive samtlige doseringsstempler (30) samtidigt,

- hvor det fælles drev omfatter en dobbeltvirkende, hydraulisk eller elektrisk aktuator, der omfatter en første hydraulisk eller elektrisk aktuator til at bevirke bevægelse af doseringsstemplerne i retningen fra startpositionen mod slutpositionen og indbefatter en anden hydraulisk eller elektrisk aktuator til at bevirke bevægelse af doseringsstemplerne i retningen fra slutpositionen mod startpositionen,

- hvor doseringsstemplerne (30) har et på forhånd bestemt fuldt slag mellem startpositionen (S) og slutpositionen (E),

- kendetegnet ved, at diameteren af doseringscylindrene og længden af det fulde slag er således, at den præcist doserede mængde leveres ved bevægelse af doseringsstemplerne (30) over en del af det maksimale slag, således at doseringsstemplerne (30) kan bevæges i delvise slag et antal gange i retningen fra startpositionen mod slutpositionen, inden doseringsstemplerne (30) skal returnere til startpositionen,

- hvilken anordning endvidere omfatter en elektronisk styreenhed (50), der er konfigureret til at aktivere den første aktuator (41, 51) til at bevæge doseringsstemplerne over et delvist slag af variabel længde, hver gang en præcis dosis cylindersmøreolie skal leveres til cylinderen (110), og den elektroniske styreenhed er konfigureret til at aktivere den anden aktuator (36, 46) for returnering af doseringsstemplerne (30) til deres startpositioner (S), når doseringsstemplerne (31) har nået deres slutpositioner (E).

2. Anordning (1) til smøring af cylindre ifølge krav 1, hvor det fælles drev omfatter:

- en stempelforbindelse (31), der er forbundet med stemplerne (30) og tilvejebragt til at bevæge doseringsstemplerne (30) i doseringscylindrene (20) samtidigt,

- en dobbeltvirkende, lineær aktuator (41, 51,36, 46), der omfatter:

  - o en første hydraulisk lineær aktuator (41, 51) til at bevirke bevægelse af doseringsstemplerne i retningen fra startpositionen mod slutpositionen, og

  - o en anden hydraulisk lineær aktuator (36, 46) til at bevirke bevægelse af doseringsstemplerne i retningen fra slutpositionen mod startpositionen.

3. Anordning (1) til smøring af cylindre ifølge krav 1 eller 2, hvilken anordning endvidere omfatter en positionssensor (44), der er indrettet til at detektere doseringsstemplernes (30) position i doseringscylindrene (20) og kommunikere med den elektroniske styreenhed (50).

4. Anordning (1) til smøring af cylindre ifølge krav 3, hvor den elektroniske styreenhed (50) bestemmer den aktuelt krævede dosis smøreolie eller modtager informationer om den aktuelt krævede dosis smøreolie og den elektriske styreenhed (50) er konfigureret til at bevæge stemplerne (30) i et delvist slag over en afstand, der svarer til den bestemte eller modtagne krævede dosis smøreolie ved aktivering af den første aktuator i overensstemmelse hermed.

5. Anordning (1) til smøring af cylindre ifølge krav 4, hvor den elektroniske styreenhed er konfigureret til at styre længden af doseringsstemplernes (30) delvise slag baseret på motorens driftsbetingelser, fortrinsvis justering af slaglængden efter motorens driftsbetingelser for hver indsprøjtning.

6. Anordning (1) til smøring af cylindre ifølge krav 5, hvor den elektroniske styreenhed (50), baseret på den målte bevægelse af doseringsstemplerne (30), bestemmer, hvor meget doseringsstemplerne (31) er bevæget i det sidste delvise slag, og hvor den elektroniske styreenhed (50) kompenserer for enhver afvigelse fra den ønskede værdi for det sidste delvise slag ved bestemmelse af den ønskede længde af doseringsstemplernes (31) efterfølgende slag.

7. Anordning (1) til smøring af cylindre ifølge et hvilket som helst af kravene 2 til 6, hvilken anordning endvidere omfatter en hydraulisk ventil (40, 140), der er forbundet med den første hydrauliske, lineære aktuator (41, 51) og forbundet med den anden hydrauliske, lineære aktuator (36, 46), og hvor den hydrauliske ventil (40) er konfigureret til at selektivt forbinde den første hydrauliske, lineære aktuator (41, 51) med en hydraulisk trykkilde og konfigureret til at selektivt forbinde den anden hydrauliske, lineære aktuator (36, 46) med den hydrauliske trykkilde.

8. Anordning (1) til smøring af cylindre ifølge krav 7, hvor den hydrauliske ventil (40) er en ventil af on/off-typen, og hvor den elektroniske styreenhed (50) er konfigureret til at styre doseringsstemplernes (30) delvise slag ved styring af længden af det tidsrum, hvor on/off-ventilen (40) forbinder den første hydrauliske, lineære aktuator (41, 51) med den hydrauliske trykkilde.

9. Anordning (1) til smøring af cylindre ifølge krav 8, hvor den elektroniske styreenhed (50) er konfigureret til at instruere on/off-ventilen (40) om at forbinde den anden hydrauliske, lineære aktuator (36, 46) med den hydrauliske trykkilde (P), når doseringsstemplerne

(30) har nået deres slutposition (E), således at doseringsstemplerne (30) ved indvirkning af den anden hydrauliske, lineære aktuator (36, 46) returnerer til deres startpositioner (S).

10. Anordning (1) til smøring af cylindre ifølge krav 8 eller 9, hvor on/off-ventilen er konfigureret til at forbinde den anden aktuator med tanken (T), mens den første hydrauliske, lineære aktuator (36, 46) er forbundet med trykkilden (P) og omvendt.

11. Anordning (1) til smøring af cylindre ifølge et hvilket som helst af kravene 7 til 10, hvor den hydrauliske ventil er en proportional ventil (140), og hvor den elektroniske styreenhed (50) er konfigureret til at justere profilformen for hastigheden for bevægelse af doseringsstemplerne (30) i et delvist slag.

12. Anordning (1) til smøring af cylindre ifølge et hvilket som helst af krav 1 til 11, hvor den elektroniske styreenhed (50) og anordningen (1) til cylindersmøring er konfigureret til at styre længden af det delvise slag og/eller doseringsstemplernes (30) hastighed baseret på specifikke driftsbetingelser for cylindrene.

13. Stor, langsomt kørende, totaktsdieselmotor med krydshoveder (100), hvilken motor omfatter:

- en flerhed af cylindre (110),

- et stempel (120), der gensidigt bevægeligt i hver cylinder

- hvor hvert af stemplerne (120) omfatter mindst to stempelringe (121), og

- en anordning (1) til smøring af cylindre ifølge et hvilket som helst af de foregående krav.

14. Stor langsomt kørende totaktsdieselmotor med krydshoveder (100) ifølge krav 13, hvor den elektroniske styreenhed (50) er både et motorstyresystem (ECS) og et styresystem til anordningen (1) til cylindersmøring

15. Fremgangsmåde til anvendelse af en anordning til smøring af cylindre (1) til en stor, langsomt kørende, flercylindret totaktsdieselmotor, der i hver cylinder (110) har et frem- og tilbagegående stempel (120) med stempelringe (121), der glider på indersiden af cylinderforingerne (111), hvorved anordningen (1) til cylindersmøring forsyner den indvendige overflade af cylinderforingerne med en præcist doseret mængde cylindersmøreolie pr. frem- og tilbagegående bevægelse eller pr. antal af frem- og tilbagegående bevægelser af cylinderen via et antal indsprøjtningssteder, der er fordelt i ensartet niveau omkring periferien af en cylinder, hvilken anordning (1) til cylindersmøring har et antal stempelpumper, hvor hver stempelpumpe har et doseringsstempel (30), der kan bevæges ved glidning i doseringscylinderen (20) mellem en startposition (S) og en slutposition (E), hvilken bevægelse af doseringsstemplerne (30) mellem startpositionen (S) og slutpositionen (E) udgør et fuldt slag, og et fælles drev (31), der indbefatter en lineær aktuator (36, 41, 46, 51) til drift af samtlige doseringsstempler (30) samtidigt i begge retninger mellem startpositionen (S) og slutpositionen (E), kendetegnet ved, at fremgangsmåden omfatter bevægelse af doseringsstemplerne (30) samtidigt ved hjælp af den lineære aktuator (36, 41, 46, 51) i et antal delvise slag fra startpositionen (S) til slutpositionen (P)

for at frembringe et antal cylinderolieindsprøjtninger, og, når doseringsstemplerne har nået deres slutposition (E), bevægelse af doseringsstemplerne (30) samtidigt ved hjælp af den lineære aktuator (36, 41, 46, 51) i ét fuldt slag fra slutpositionen (E) tilbage til startpositionen (S).

16. Fremgangsmåde ifølge krav 15, hvilken fremgangsmåde endvidere omfatter bestemmelse eller opnåelse af den aktuelt krævede dosis smøreolie og instruktion af den lineære aktuator om at bevæge doseringsstemplerne (30) i et delvist slag over en afstand, der svarer til den bestemte eller modtagne krævede smøreoliedosis.

17. Fremgangsmåde ifølge krav 16, hvilken fremgangsmåde endvidere omfatter måling af doseringsstemplernes (30) bevægelse i det sidste delvise slag og kompenserer for enhver afvigelse fra den ønskede værdi for det sidste delvise slag, når den lineære aktuator (36, 41, 46, 51) instrueres om at bevæge det næste delvise slag, navnlig når det sidste delvise slag er kort på grund af, at doseringsstemplerne (30) når enden af deres slag.

18. Fremgangsmåde ifølge et hvilket som helst af kravene 15 til 17, hvilken fremgangsmåde endvidere omfatter justering af længden af et delvist slag for doseringsstemplerne (30) som reaktion på motorens driftsbetingelser.

19. Fremgangsmåde ifølge krav 18, hvilken fremgangsmåde endvidere omfatter justering af længden af et delvist slag for doseringsstemplerne (30) for hver indsprøjtning.

20. Fremgangsmåde ifølge et hvilket som helst af kravene 15 til 19, hvor anordningen (1) til cylindersmøring omfatter en hydraulisk ventil (40), der er forbundet med den første hydrauliske, lineære aktuator (41, 51) og forbundet med den anden hydrauliske, lineære aktuator (36, 46) og fremgangsmåden omfatter selektivt at forbinde den første hydrauliske, lineære aktuator (41, 51) med en hydraulisk trykkilde og er konfigureret til selektivt at forbinde den anden hydrauliske, lineære aktuator (36, 46) med den hydrauliske trykkilde.

21. Fremgangsmåde ifølge krav 20, hvilken fremgangsmåde endvidere omfatter tryksætning af den første hydrauliske, lineære aktuator (41, 51) for at bevæge doseringsstemplerne (30) over en del af deres totale slaglængde og tryksætning af den anden hydrauliske, lineære aktuator (41, 51) for kun at returnere stemplerne (30), når doseringsstemplerne har nået deres slutposition (E).

22. Fremgangsmåde ifølge krav 19 eller 20, hvor den hydrauliske ventil (40) er en ventil af on/off-typen, og hvor fremgangsmåden omfatter styring af doseringsstemplernes (30) delvise slag ved at styre længden af den periode, hvor on/off-ventilen (40) forbinder den første hydrauliske, lineære aktuator (41, 51) med den hydrauliske trykkilde.

23. Fremgangsmåde ifølge krav 22, hvor fremgangsmåden omfatter styring af den hydrauliske on/off-ventil (40), således at stemplerne (30) bevæges med slag af en kontinuerligt variabel længde, der er justeret for hver indsprøjtning efter motorens driftsbetingelser, og ved at tilvejebringe en pulsperiode til on-off-ventilen (40) for at åbne for on-off-ventilen (40) i

et på forhånd fastsat tidsrum svarende til en på forhånd bestemt dosis smørefluid.

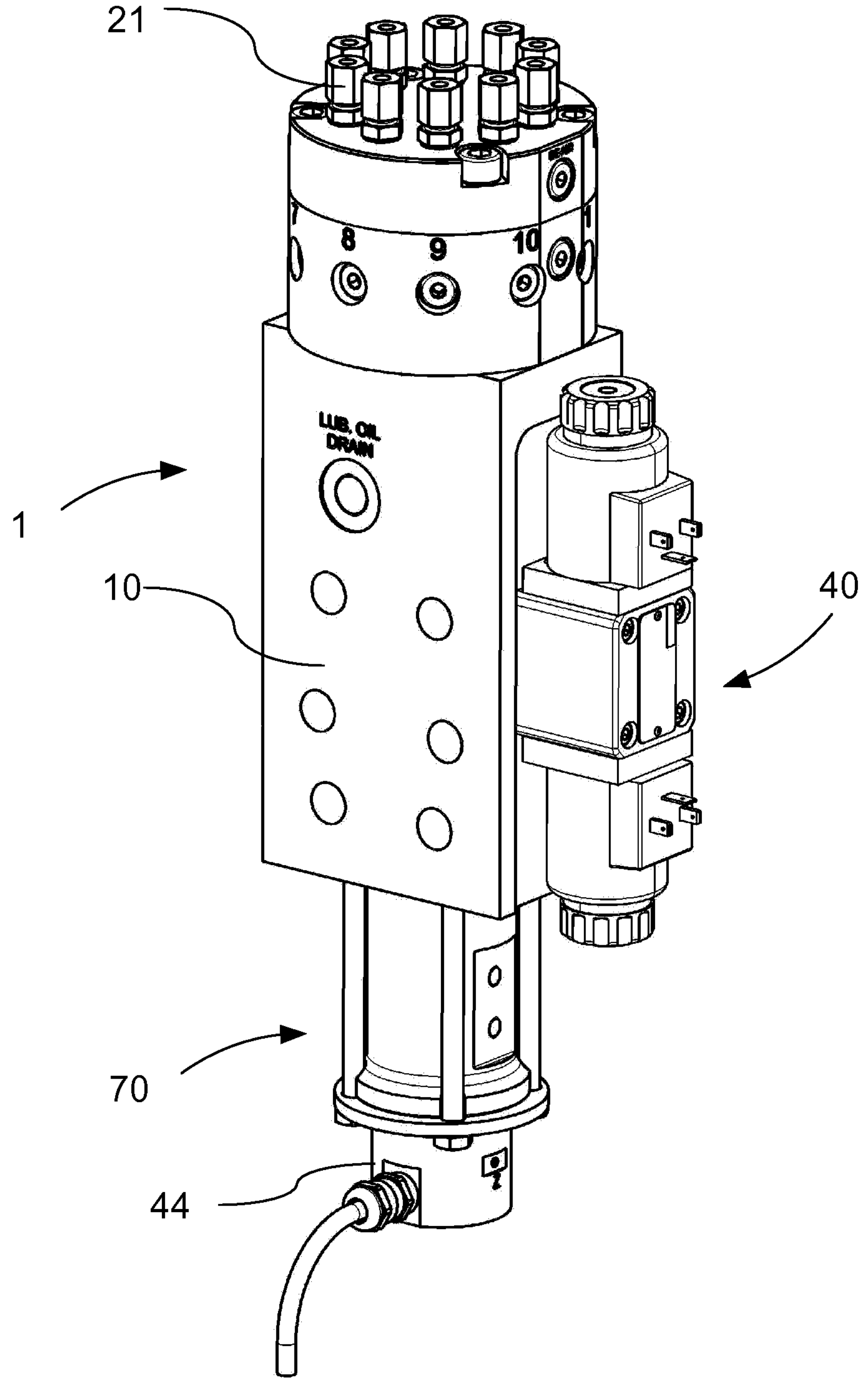

Fig. 1

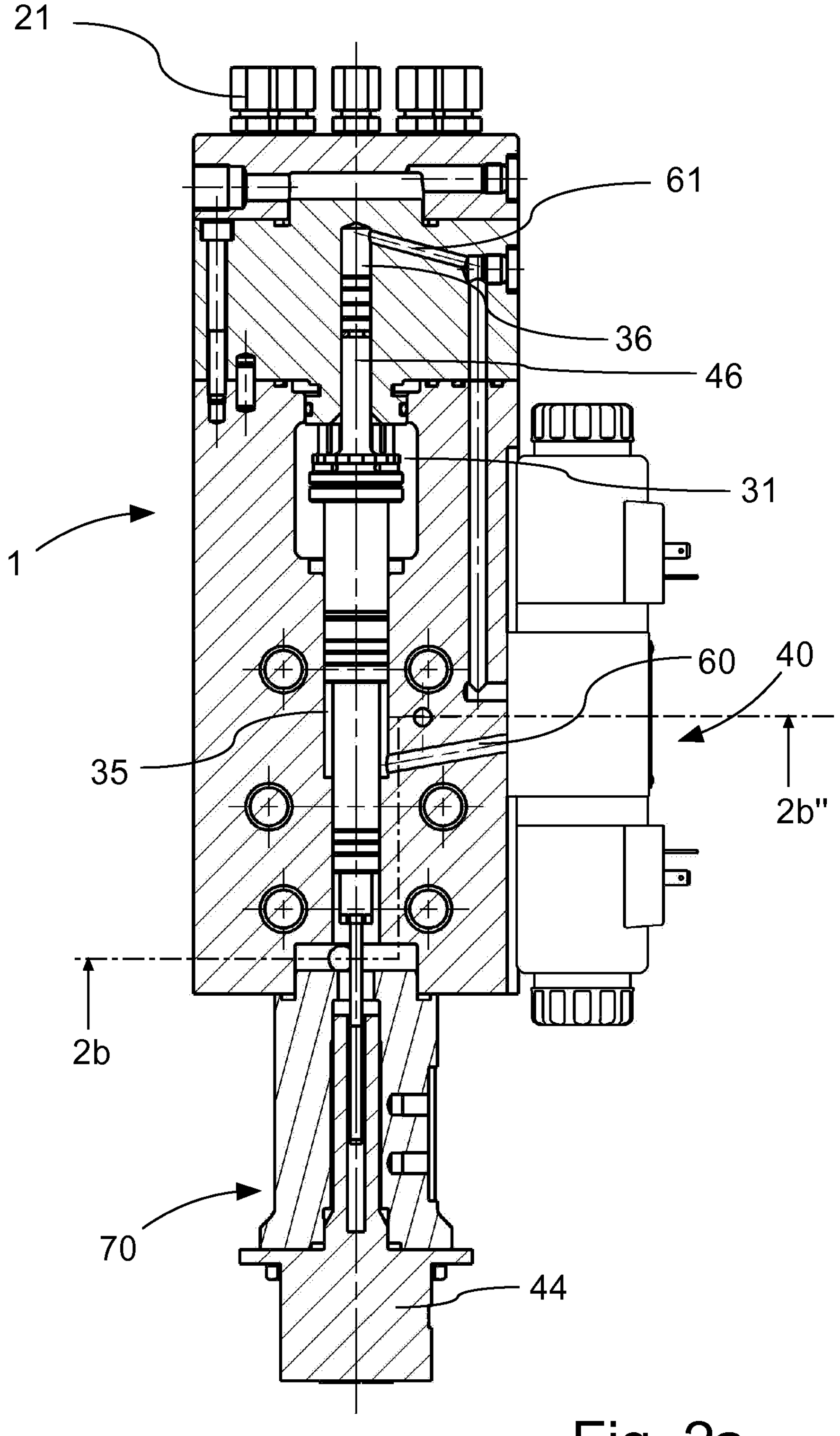

Fig. 2a

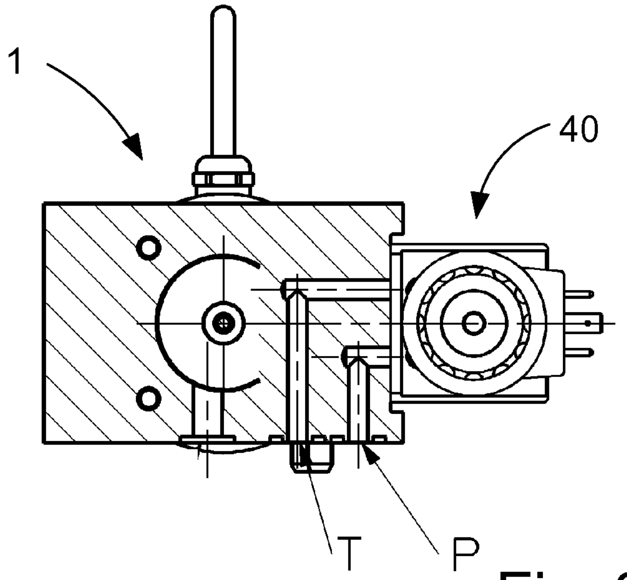

Fig. 2b

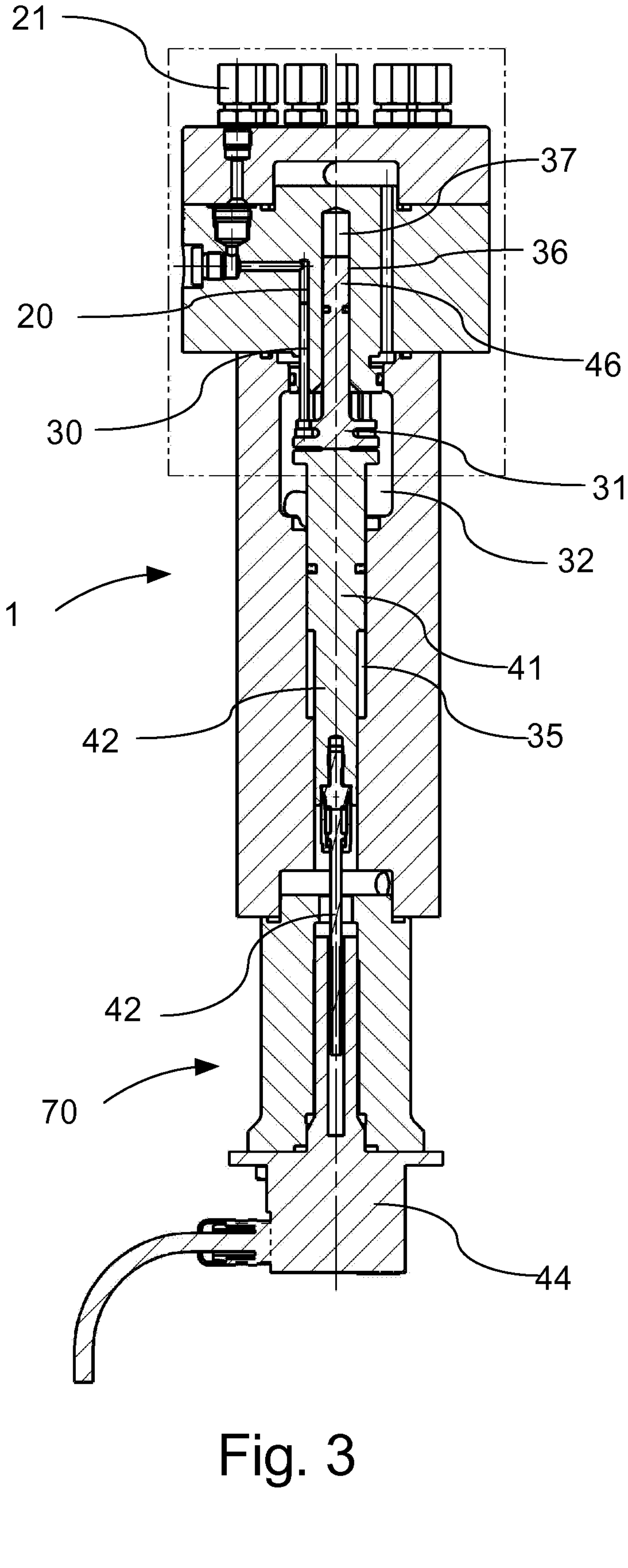

Fig. 3

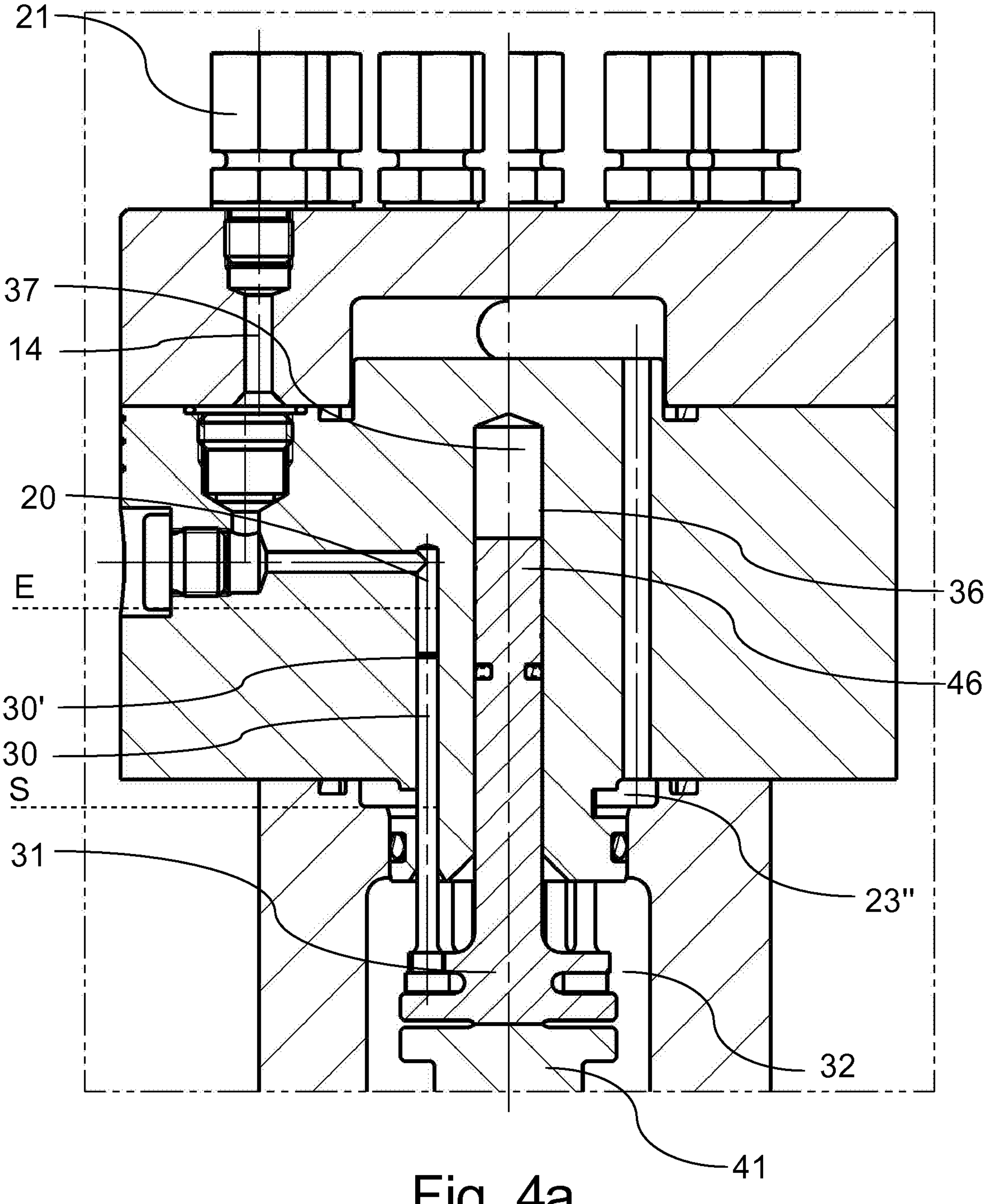

Fig. 4a

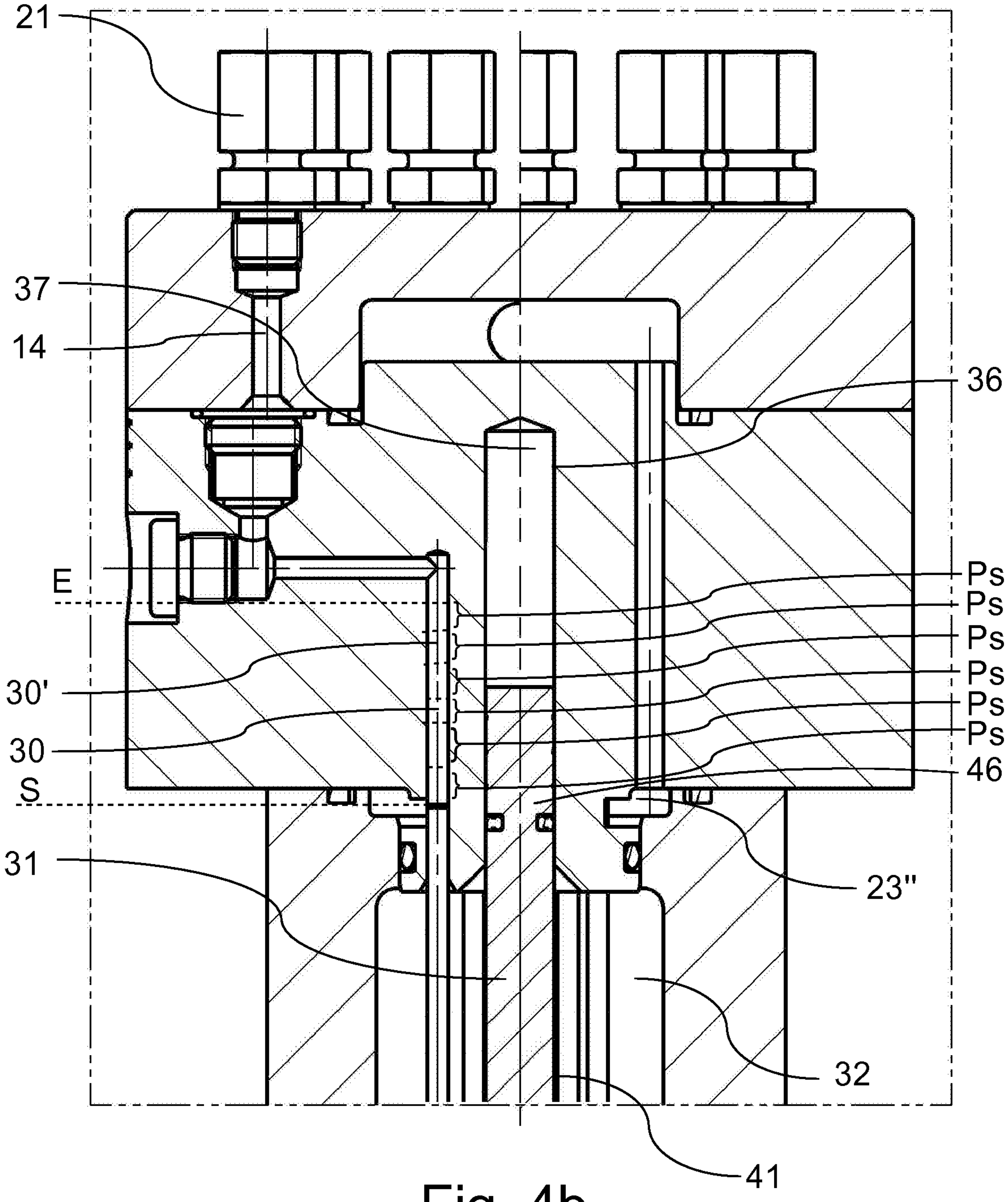

Fig. 4b

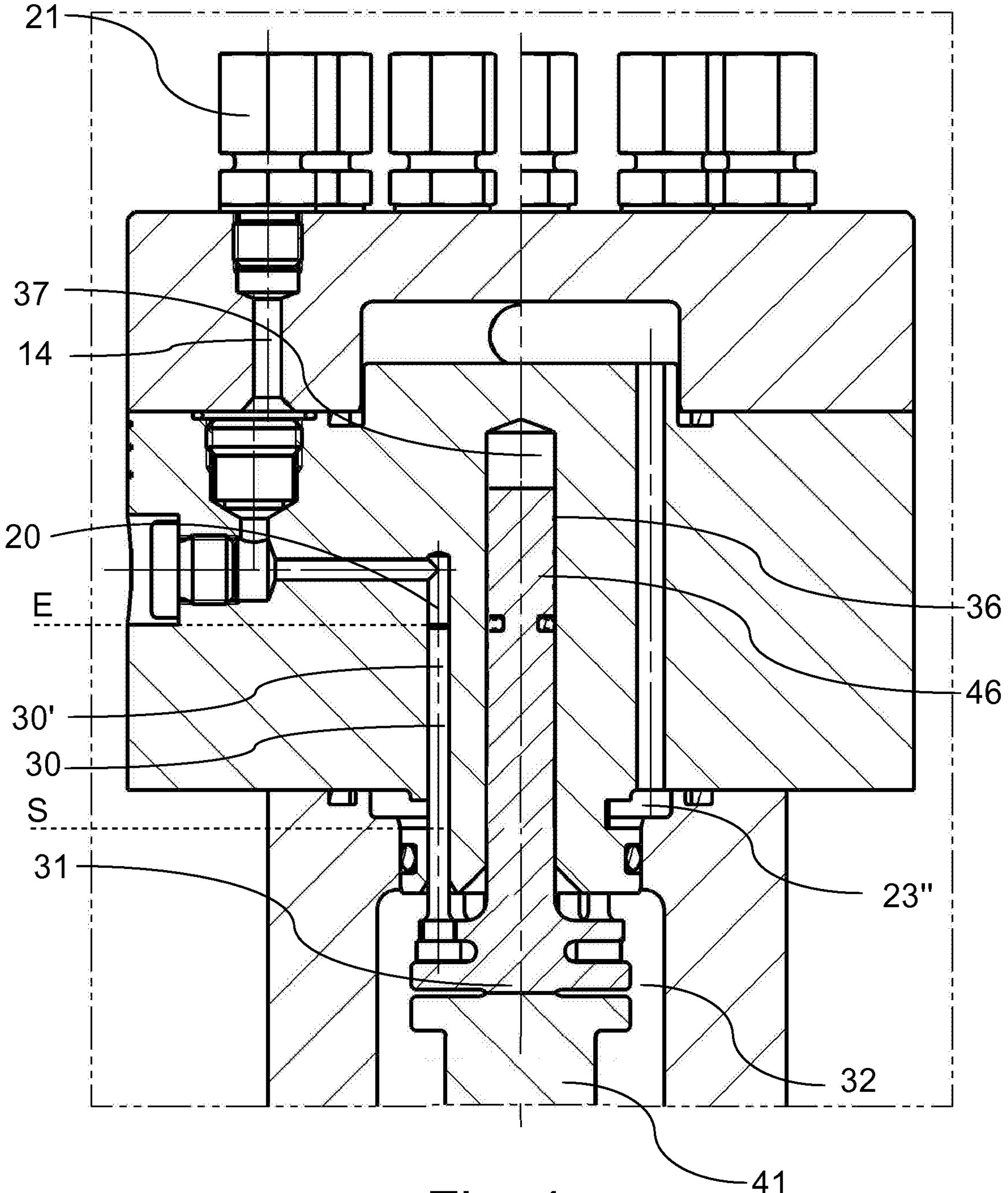

Fig. 4c

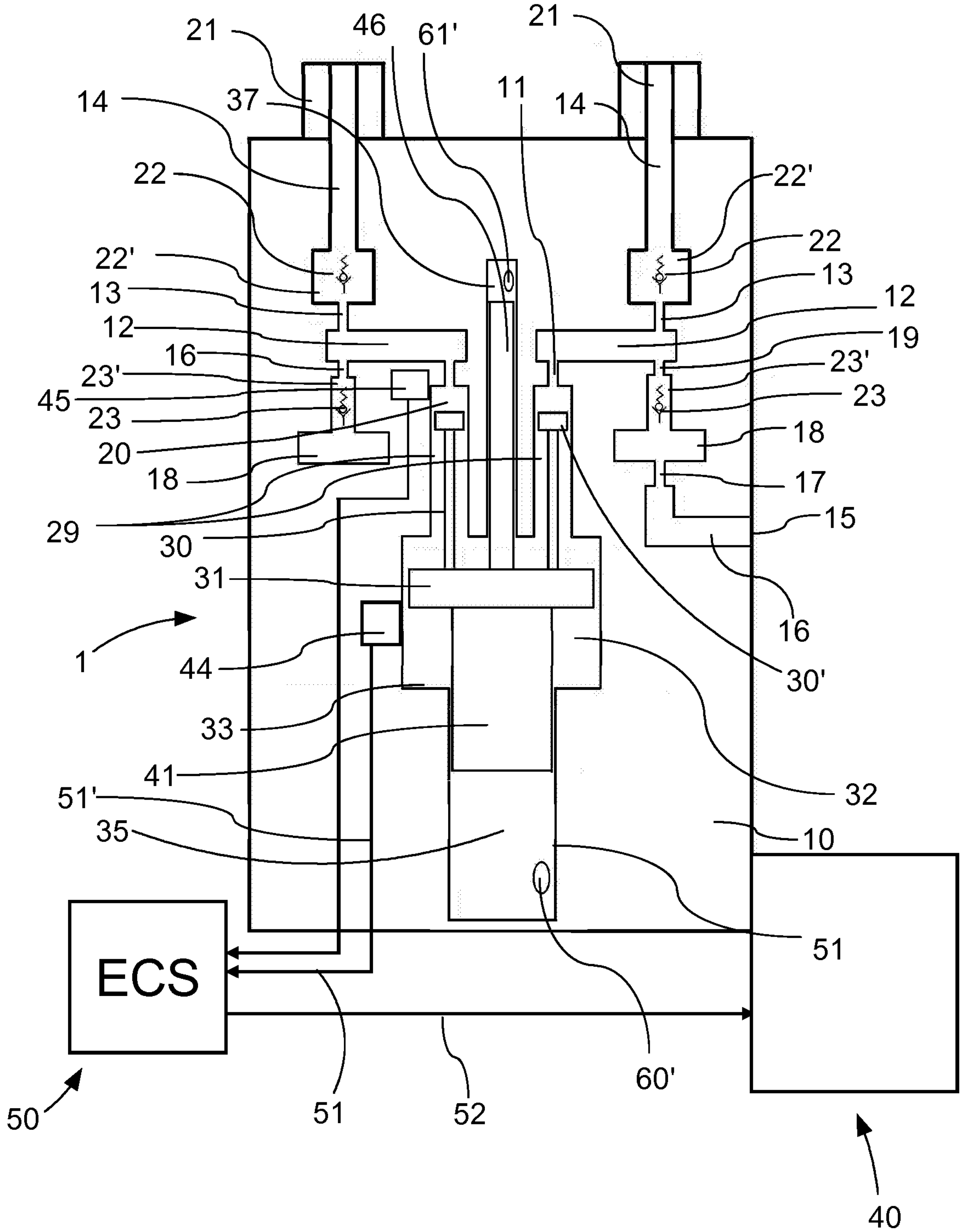
21
46
61'
21
14
37
11
14
22
22'
22'
22
13
13
12
12
16
19
23'
23'
45
23
23
20
18
18
17
29
30
15
31
16
1
44
30'
33
41
32
51'
35
10
ECS
51
60'
51
52
50
40

Fig. 5

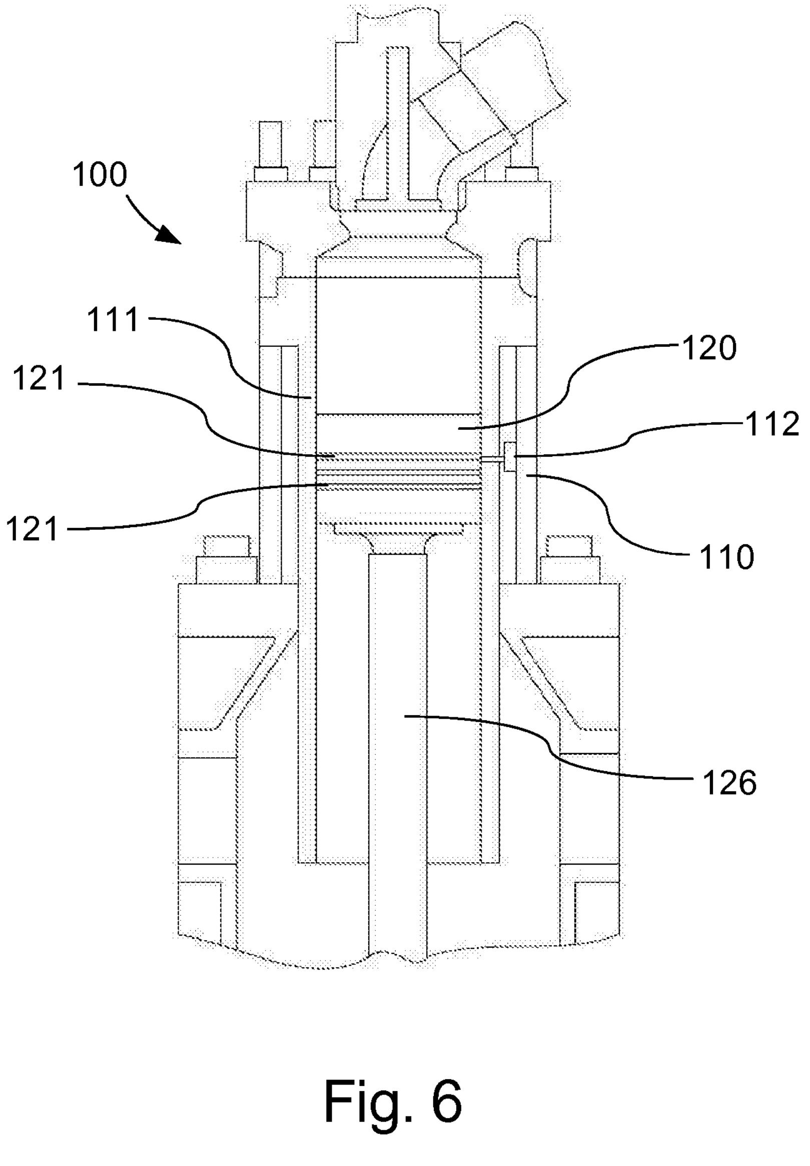

Fig. 6

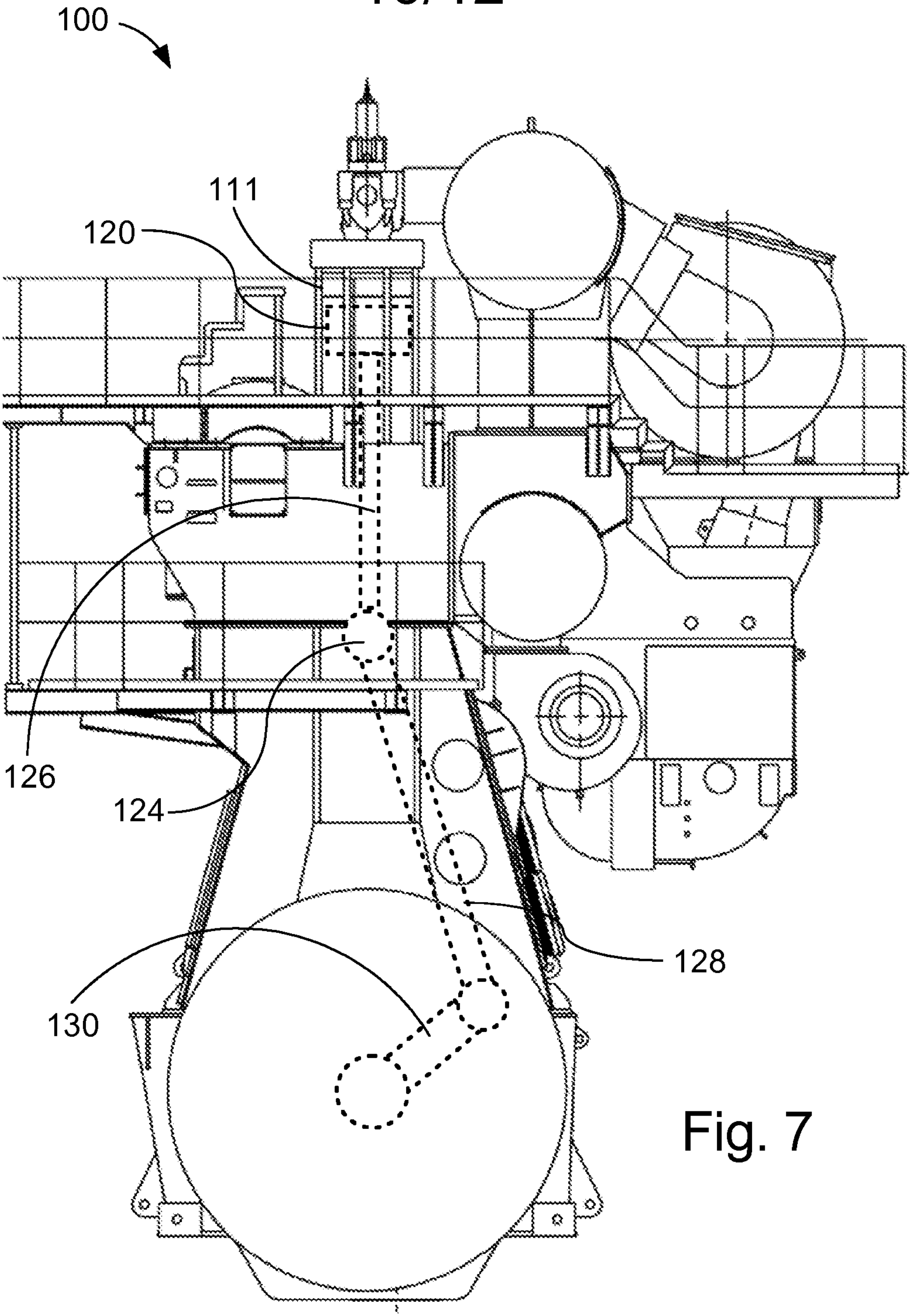

Fig. 7

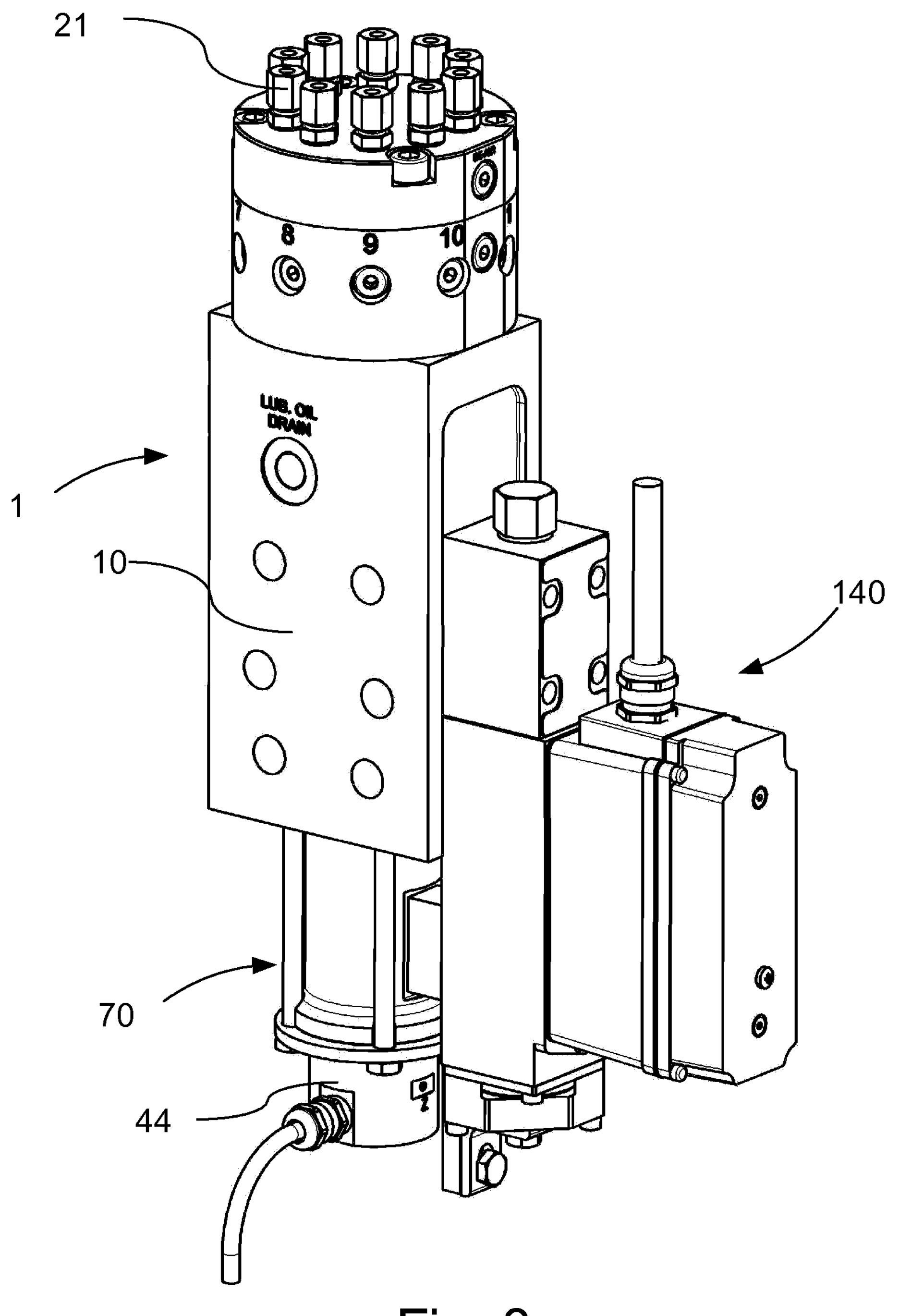

Fig. 8

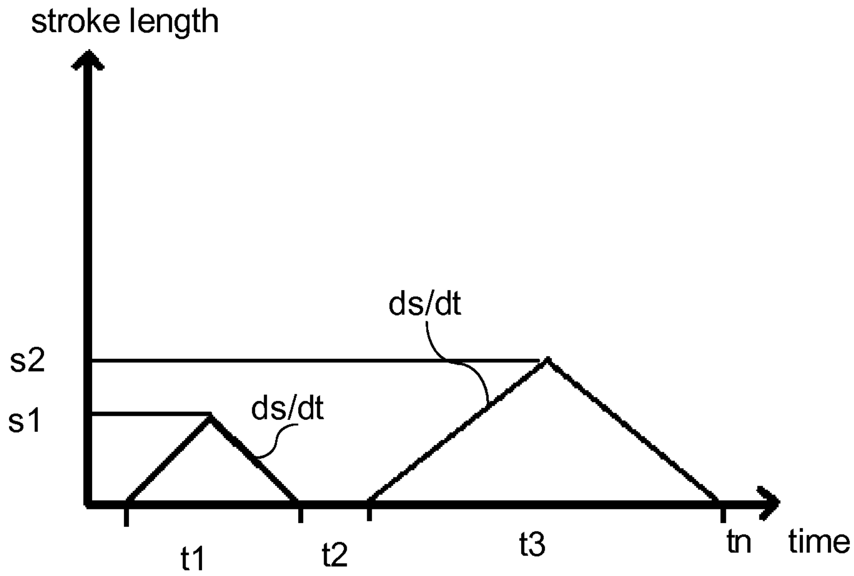

Fig. 9